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THE SCIENTIFIC MONTHLY

NOVEMBER, 1922

SOCIAL LIFE AMONG THE INSECTS[1]

By Professor WILLIAM MORTON WHEELER

BUSSEY INSTITUTION, HARVARD UNIVERSITY

LECTURE IV—ANTS, THEIR DEVELOPMENT, CASTES, NESTING AND FEEDING HABITS

ON one occasion several years ago when I was about to lecture on ants in Brooklyn, a gentleman introduced me to the audience by quoting the sixth to eighth verses of the sixth chapter of Proverbs, and then proceeded in utter seriousness to give an intimate account of their author. He said that Solomon was the greatest biologist the Hebrews had produced, that he had several large and completely equipped laboratories in which he busied himself throughout his reign with intricate researches on ant behavior and that the 700 wives and 300 concubines mentioned in the Bible were really devoted graduate students, who collaborated with the king in his myrmecological investigations. The gentleman deplored the fact that the thousand and one monographs embodying their researches had been lost, and concluded by saying that he was delighted to introduce one who could supply the missing information. As he had consumed just forty-three minutes with his account of Solomon and his collaboratrices, I had to confess my inability to "deliver the goods" in the remaining seventeen. From what recondite sources of biblical exegesis the Brooklyn gentleman drew his information I have never been able to ascertain, but I am sure that Solomon's few myrmecological comments, which have come down to us from about 970 B. C., are very accurate—far more accurate than that story of Herodotus, written some 500 years later, of the gold-digging ants of India, which were as large as leopards, and whose hides were seen by Nearchus in the camp of Alexander the Great, and whose horns were mentioned by Pliny as hanging, even in his time, in the temple of Hercules at Erythræ.

[1] Lowell Lectures.

This and the many other ant stories invented or disseminated by ancient and modern writers are certainly not devoid of interest, but the actual behavior of the insect is so much more fascinating that you will pardon me for not dwelling on them.

The Formicidæ constitute the culminating group of the stinging Hymenoptera and have attracted many investigators for more than a century and especially during the past thirty years. Unlike the honeybee these insects make no appeal to our appetites nor even to that vague affection which we feel for most of the common denizens of our forests, fields and gardens, but only to our inquisitiveness and anxiety. Hence the vast literature which has been written on the ants may be said to have been prompted by scientific, philosophic or mere idle curiosity or by our instinct of self-preservation. In the presence of the ant we experience most vividly those peculiar feelings which are aroused also by many other insects, feelings of perplexity and apprehension, which Maeterlinck has endeavored to express in the following words: "The insect does not belong to our world. Other animals and even the plants, despite their mute lives and the great secrets they enfold, seem not to be such total strangers, for we still feel in them, notwithstanding all their peculiarities, a certain terrestrial fraternity. They may astonish or even amaze us at times, but they do not completely upset our calculations. Something in the insects, however, seems to be alien to the habits, morals and psychology of our globe, as if it had come from some other planet, more monstrous, more energetic, more insensate, more atrocious, more infernal than our own. With whatever authority, with whatever fecundity, unequalled here below, the insect seizes on life, we fail to accustom ourselves to the thought that it is an expression of that Nature whose privileged offspring we claim to be. . . . No doubt, in this astonishment and failure to comprehend, we are beset with an indefinable, profound and instinctive uneasiness, inspired by beings so incomparably better armed and endowed than ourselves, concentrations of energy and activity in which we divine our most mysterious foes, the rivals of our last hours and perhaps our successors. . . ."

The similarities which the ants, as one of several families of aculeate or stinging Hymenoptera, necessarily bear to the wasps and bees, are so overlaid by elaborate specialization and idiosyncrasies that their primitive vespine characters are not very easily detected. I wish to dwell on some of these specializations, but before doing so, it will be advisable to give under separate captions a brief summary of what I conceive to be the fundamental peculiarities of the ants:

(1) The whole family Formicidæ consists of social insects, that is, it includes no solitary nor subsocial forms such as we found among the beetles, wasps and bees. We are therefore unable to point to any existing insects that might represent stages leading up to the social life of the ants. Within the family, nevertheless, we can distinguish quite a number of stages in a gradual evolution of social conditions from very simple, primitive forms, whose colonies consist of only a few dozen individuals, with a comparatively feeble caste development, to highly specialized forms with huge colonies, comprising hundreds of thousands of individuals and an elaborate differentiation of castes.

(2) The number of described species of ants is approximately 3,500, but if we include their subspecies and varieties, many of which will probably be raised to specific rank by future, less conservative generations of entomologists, we shall have more than double the number. This is far in excess of the number of all other social insects, including both the groups I have already considered and the termites. The ants are therefore the dominant social insects.

(3) This dominance is shown also by their geographical distribution, which is world-wide. There are ants everywhere on the land-masses of the globe, except in high arctic and antarctic latitudes and on the summits of the higher mountains. The number of individual ants is probably greater than that of all other insects. With few exceptions, the termites are all confined to tropical or subtropical countries, and the number of social wasps and bees in temperate regions is very small.

(4) We found that the social wasps arose from the Eumenine solitary wasps and the bees from the solitary Sphecoids. All the authorities agree that the ants had their origin in neither of these ancestral stocks, but among the Scolioids, a distinct offshoot of the primitive Vespoids. Of the four modern families of the Scolioids, the Psammocharidæ, Thynnidæ, Mutillidæ and Scoliidæ, the last seems to be most closely related to the ants. Since they must be traced to ancestors which were winged in both sexes, the Thynnids and Mutillids, which have wingless females, are excluded, and the family Psammocharidæ is not very closely allied to the Formicidæ.

(5) The ants, unlike the social wasps and bees, are eminently terrestrial insects. They inherited and seem very early to have exaggerated the terrestrial habits of their primitive Scolioid ancestors. The majority of the species in all parts of the world still nest in the soil. Many of them later took to nesting in dead or decaying wood, and more recently a number of species, especially in the rain-forests of the tropics, have become arboreal and nest by preference in the twigs of trees and bushes or construct paper or

silken nests among the leaves and branches. The terrestrial habit led to a permanent phylogenetic suppression of the wings in the workers, an ontogenetic loss of the wings in the queens and a diminution of the eyes in both of these castes. A few very archaic ants still possess large eyes like the wasps and bees, but in the great majority of species, which are more or less subterranean, and therefore practically cave-animals during much of their lives, the eyes have dwindled, and in many species have almost or completely disappeared. The great abundance of ants in the desert, savanna and prairie regions of the globe indicates that they arose during some period of the Mesozoic, perhaps during the Triassic or Liassic, when the climate was warm but arid. Their extensive adaptation to low, damp jungles, with their rank vegetation, seems to have developed during the Cretaceous or early Tertiary. The ants therefore resemble the solitary wasps, which are still conspicuously abundant in hot, arid regions. Both groups are represented by only a small number of species in cool, moist regions, like New Zealand, the British Isles and certain mountain ranges, like the Selkirks of British America.

(6) In the social wasps and bees we found that the worker,

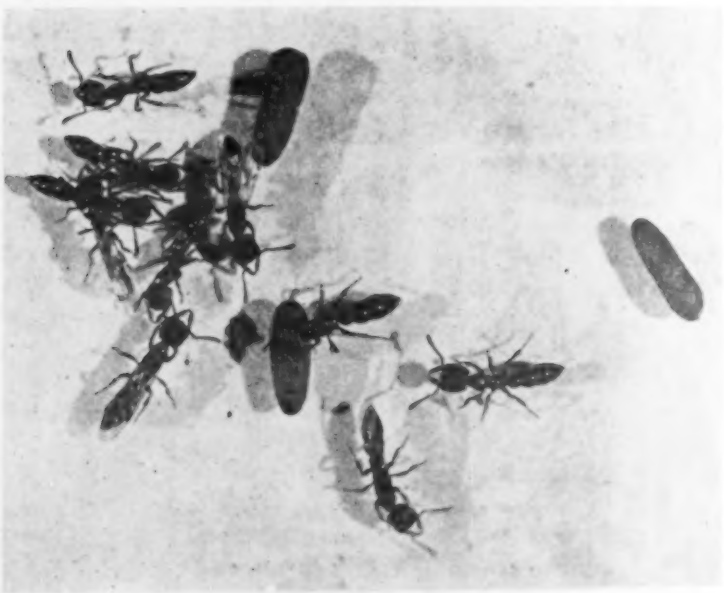


FIG. 54

Stigmatomma pallipes, a primitive, subterranean Ponerine ant of the United States. The winged individuals are virgin queens and are very similar to the workers. Nearly twice natural size. (Photograph by J. G. Hubbard and O. S. Strong.)

or sterile caste, though distinctly differentiated, is, nevertheless, very much like the queen, or fertile female. In ants the differences are much greater. Even when, as in many primitive ants (Fig. 54), the worker resembles the queen in size and form, it never possesses wings, and in most ants the two castes are so dissimilar that they have often been described as separate species. The male ant, too, is much less like the queen than is the corresponding sex among the social wasps and bees (Fig. 57). It is evident, therefore, that all three castes are more highly specialized. In many ants, as we shall see, the worker, queen and male may each become differentiated into two or more castes, a phenomenon which is nowhere even suggested among the wasps and bees.

(7) Very long and intimate contact with the soil has made the ants singularly plastic in their nesting habits. While most social wasps and bees construct elaborate combs with very regular, hexagonal cells of such expensive substances as paper and wax, the ants merely make more or less irregular galleries or chambers in the soil or dead wood or if they construct paper or silken nests avoid a rigid type of architecture. Hence the great variability of nesting habit in the same species. This plasticity and saving of time and labor are very advantageous, because they enable the insects, when conditions of temperature or moisture become unfavorable or when bothersome enemies settle too near the nest, to change their habitation readily and without serious loss to the colony. Espinas long ago noticed the importance of the terrestrial habits of ants. He says: "Ants owe their superiority to their terrestrial life. This assertion may seem paradoxical, but consider the exceptional advantages afforded by a terrestrial compared with an aërial medium in the development of their intellectual faculties! In the air there are the long flights without obstacles, the vertiginous journeys far from real bodies, the instability, the wandering about, the endless forgetfulness of things and of oneself. On the earth, on the contrary, there is not a movement that is not a contact and does not yield precise information, not a journey that fails to leave some reminiscence; and as these journeys are determinate, it is inevitable that a portion of the ground incessantly traversed should be registered, together with its resources and its dangers, in the animal's imagination. Thus there results a closer and much more direct communication with the external world. To employ matter, moreover, is easier for a terrestrial than an aërial animal. When it is necessary to build, the latter must, like the bee, either secrete the substance of its nest or seek it at a distance, as does the bee when she collects propolis, or the wasp when she gathers material for her paper. The terrestrial animal has its building materials close at hand, and its architecture may be as

varied as these materials. Ants, therefore, probably owe their social and industrial superiority to their habitat."

(8) The plasticity of ants is shown even more clearly in their care of their young, which are not reared in separate cells but in clusters and lie freely in the chambers and galleries of the nest where they can be moved about and easily carried away or hidden when the colony is disturbed or the moisture and temperature conditions are unfavorable. Like their continual contact with their physical environment, their intimate acquaintance with their young in all their stages has been an important factor in the high psychological development of the Formicidæ.

(9) A similar plasticity characterizes their feeding habits. As a group they feed on an extraordinary range of substances: the bodies and secretions of other insects, seeds, delicate fungi, nectar, the saccharine excreta of plant-lice, scale insects, etc. Some species seem to be almost omnivorous.

(10) All this adaptability, or plasticity in nesting and feeding habits is, of course, an expression of a very active and enterprising disposition and has resulted in the formation of a vast and intricate series of relationships between ants and other organisms, including man. These restless, indefatigable, inquisitive busybodies, forever patrolling the soil and the vegetation in search of food, poke their noses, so to speak, into the private affairs of every living thing in their environment. Nor do they stop at this; they actually draw many organisms, by domesticating them or at any rate attaching them to their nests or bodies, into the vortex of their ceaseless, impudent activities. Nearly every week during the past twenty years I have received from some entomologist somewhere on our planet one or more vials of ants with a request for their identification, often because they had been found associated with some insect or plant which the sender happened to be investigating. In the next lecture I shall describe a number of the strange partnerships into which ants have entered as a result of their inordinate and unappeasable appetites.

As my time is limited I shall select for discussion only a few of the topics suggested in the foregoing summary, namely, the main taxonomic divisions of the family Formicidæ, polymorphism, or the development of castes, the origin and growth of colonies, the structure of the alimentary canal in adult and larval ants and the evolution of the feeding habits.

In their main outlines, at least, the phylogenetic relationships of the various subdivisions or subfamilies of the Formicidæ have been clearly established. There are seven of them: the Ponerinæ, Cerapachyinæ, Dorylinæ, Pseudomyrminæ, Myrmicinæ, Dolicho-

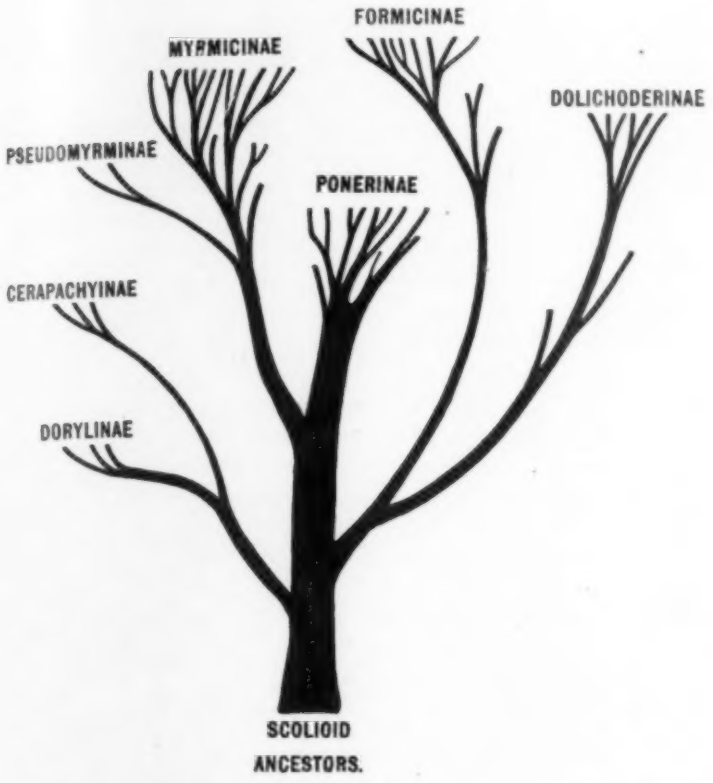


FIG. 55

Ancestral tree showing the putative phylogenetic relations of the family Formicidæ as a whole and of its subfamilies to one another.

derinæ and Formicinæ. The Ponerinæ constitute the primitive, basic stock of the family and have given rise to the six other subfamilies, which are represented in the ancestral tree (Fig. 55) as so many branches. Their thickness roughly indicates their vigor or comparative development and their height their degree of specialization and dominance in the existing fauna. All the subfamilies are well represented in the tropics of both hemispheres, but in the north temperate region nearly all the species belong to the two largest and highest subfamilies, the Myrmicinæ and Formicinæ. In temperate North America and Eurasia there are very few Dolichoderinæ and Ponerinæ and no Cerapachyinæ nor Pseudomyrminæ. A small number of Dorylinæ extend as far north as Colorado, Missouri and North Carolina (35° to 40°) and to about the same latitude on the southern shores of the Mediterranean.

With the exception of a series of peculiar parasitic genera, which are represented only by males and females, all ants possess a sharply defined worker caste. In primitive groups, like the

Ponerinæ, Cerapachyinæ and Pseudomyrminæ, the worker is nearly as large as the queen but lacks the wings and has therefore a more simply constructed thorax, the compound eyes are smaller and the simple eyes or ocelli are minute or absent. In the three subfamilies mentioned the worker is monomorphic, that is, it always has the same form though it may vary somewhat in size. In the four remaining subfamilies (Dorylinæ, Myrmicinæ, Dolichoderinæ and Formicinæ) we find the same uniformity of the worker in many species, but in a considerable number it has become highly variable, or polymorphic, as a result of agencies which have acted independently in each subfamily or even within the limits of a single genus (Figs. 57 and 58). In such cases the workers can be arranged in a graduated series, beginning with large, huge-headed individuals more like the queen in stature, and ending with minute, small-headed individuals, which may be very much smaller than the queen. Such a series exhibits not only great morpholog-

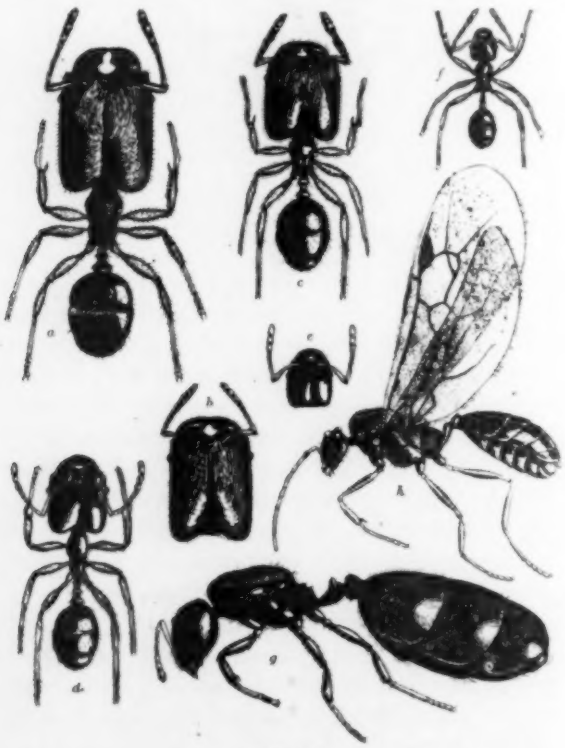


FIG. 57

A small Myrmicine harvesting ant of Texas, *Pheidole instabilis*, with polymorphic worker caste. *a*, soldier; *f*, worker; *b* to *e*, forms intermediate between the soldier and worker (lacking in most other species of the huge genus Pheidole); *g*, queen (deälated); *h*, male. The figures are all drawn to the same scale.

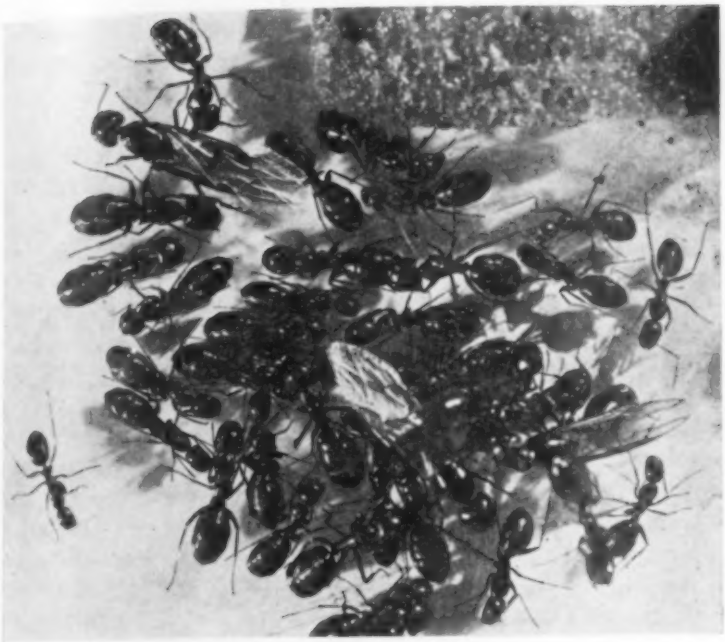


FIG. 58

Portion of a colony of a common Formicine ant (*Camponotus americanus*), comprising virgin, winged queens and workers, the latter showing the unstable polymorphism in stature and size of head, characteristic of most species of the genus. (Photograph by J. G. Hubbard and O. S. Strong.)

ical but also great functional differences among its members. The largest individuals commonly act as policemen or defenders of the colony, but in some species their powerful jaws enable them to crush seeds or the hard parts of insects, so that the softer parts may be exposed and eaten by the smaller individuals (Fig. 57). The latter excavate the nest, forage for food, nurse the young and in some species devote all their energies to the cultivation of the fungus gardens. In a graduated series like the one described we usually call the largest workers "maximæ," the smallest "minimæ" and the intermediate forms "mediæ," the word "operariæ" (workers) being understood in each case. Now in some ants only the two extremes, the maximæ and the minimæ, of the polymorphic series proved to be serviceable to the colony, so that all the intermediate forms (mediæ) have been eliminated, leaving the worker caste distinctly dimorphic. In such ants we call the maximæ "soldiers" (*milites*) and the minimæ "workers" (*operariæ*). This condition has been attained in several genera and subgenera among the Myrmicinæ and Formicinæ (Pheidole (Fig. 57), Oligomyrmex, Colobopsis, etc.). In still other genera,

where soldiers were not needed or were too expensive to rear and maintain, on account of their great size and appetites, they too have been eliminated and the worker caste is represented only by the tiniest individuals of the originally polymorphic series (Carebara, Tranopelta, Pædalgus, Solenopsis, etc.). There is therefore an enormous difference in these ants in size and structure between the queen and the only surviving worker form of the species. In Carebara, *e. g.*, the queen is several thousand times as large as the worker! Nevertheless, both are merely extreme female forms of the same species and may, of course, develop from the eggs of the same mother.

But the worker is not the only caste that has become dimorphic. In some species there are two distinct forms of queen, in others two distinct forms of male. In these cases one of the forms is winged, the other usually apterous. And here again, by suppression of the winged female or winged male, the wingless form may become the only surviving fertile form of its sex in the species. All these developments are interesting because they indicate that the distinctions among the various castes have arisen gradually by continuous or fluctuating variations and that the survival and persistence of some of them and the elimination of others have led to the sharply discontinuous series of castes which we find in many ants.

It is obvious that some of the differences between the various castes, especially those in size, are due to differences in the amount of food consumed during the larval stages, but the profounder morphological differences which separate the queens, soldiers and workers, must be due to other causes. We must suppose either that the food administered to the larvæ differs in quality or that there are several different kinds of eggs, some of which develop into fertile, other into sterile forms. In a sense the latter would be mutations, like the various sterile forms of the evening primrose, which make their appearance generation after generation from some of the seeds of the fertile forms. In the case of the ants, however, we find that the workers not infrequently lay viable eggs, and though they are never fertilized and generally develop into males, the latter may mate with queens and thus be a means of establishing a representation of the characters of their worker mothers in the germ-plasm of the species. The peculiar anomalies known as gynandromorphs, that is, individuals partly male and partly female, which occasionally occur among ants, also indicate that the queens, soldiers and workers arise from as many different kinds of eggs, since there are three different kinds of gynandromorphs, exhibiting respectively combinations or mosaics of male and queen, male and soldier and male and worker characters. It

is difficult to see how such perfectly definite combinations could be produced by larval feeding, and it is equally difficult to account for them as the results of internal secretions. In the present state of our knowledge we can only surmise that the differences between the queen and worker castes were originally ontogenetic and determined by feeding, as they still are in the social wasps and bees, but that in the ants the germ-plasm has somehow been reached and modified, so that an hereditary basis for caste differentiation has been established.

The ant colony may be initiated and developed by one of two different methods which I shall call the independent and the dependent. The former is peculiar to the nonparasitic, the latter to the parasitic species. Leaving an account of the ants which employ the dependent method for the next lecture, I would say that the great majority of ants establish their colonies in essentially the same manner as Vespa and the bumble-bees. The winged, virgin queen, after fecundation during her nuptial flight, descends to the ground, rids herself of her wings and seeks out some small cavity under a stone or piece of bark, or excavates a small cell in the soil. She then closes the opening of the cell and remains a voluntary prisoner for weeks or even months while the eggs are growing in her ovaries. The loss of the wings has a peculiar effect on the voluminous wing-muscles in her thorax, causing them to break down and dissolve in the blood plasma. Their substance is carried by the circulation to the ovaries and utilized in building up the yolk of the eggs. As soon as the eggs mature, they are laid and the queen nurses the hatching larvæ and feeds them with her saliva till they pupate. Since she never leaves the cell during all this time and has access to no food, except the fat she stored in her abdomen during her larval life and her dissolved wing-muscles, the workers that emerge from the pupæ are all abnormally small. They are, in fact, always minimæ in species which have a polymorphic worker caste. They dig their way out through the soil, thus establishing a communication between the cell and the outside world, collect food for themselves and their mother and thus enable her to lay more eggs. They take charge of the second brood of eggs and larvæ, which, being more abundantly fed, develop into larger workers. The population of the colony now increases rapidly, new chambers and galleries are added to the nest and the queen devotes herself to digesting the food received from the workers and to laying more eggs. In the course of a few years numerous males and queens are reared and on some meteorologically favorable day the fertile forms from all the nests of the same species over a wide expanse of country escape simultaneously into the air and celebrate their marriage flight. This flight provides

not only for the mating of the sexes but also for the dissemination of the species, since the daughter queens, on descending to the ground, usually establish their nests at some distance from the parental colony.

It will be seen that the queen ant, like the queen wasp and bumble-bee, but unlike the queen honeybee, is the perfect female of her species, possessing not only great fecundity but in addition all the worker propensities, as shown by her ability to make a nest and bring up her young. But as soon as the first brood of workers appears, these propensities are no longer manifested. That they are not lost is shown by the simple experiment of removing the queen's first brood of workers. Then, provided she be fed or have a sufficient store of food in her body, she will at once proceed to bring up another brood in the same manner as the first, although she would have manifested no such behavior under normal conditions.

As already stated, this independent method of colony formation is the most universal and is followed alike by tropical and extratropical ants. It is undoubtedly the primitive method and, as we shall see, the one from which the dependent method has been derived. It differs from that of Vespa and Bombus, nevertheless, in leading to the formation of perennial colonies even in temperate and boreal regions. The queen ant may, in fact, live from 12 to 17 years and although, like other aculeates, she is fecundated only once, may produce offspring up to the time of her death. Unlike the queen honeybee she is never hostile to her own queen daughters, and in many species of ants some of these daughters may return after their marriage flight to the maternal colony and take a very active part in increasing its population. In this manner the colony may become polygynic or pleometrotic, and in some instances may contain a large number of fertile queens. When such a colony grows too large it may separate into several, the queens emigrating singly or in small companies, each accompanied by a detachment of workers, to form a new nest near the parental formicary. This behavior is exhibited by the well-known mound-building ant (*Formica exsectoides*) of our New England hills. You will notice that its mounds usually occur in loose groups or clusters and that the workers of the different nests are on friendly terms with one another and sometimes visit back and forth. We may, of course, call the whole cluster a single (polydomous) colony, but it really differs from a number of colonies only in the absence of hostility between the inhabitants of the different mounds. In certain tropical ants, like the Dorylinæ (Figs. 59 and 60), however, I am inclined to believe that the only method of colony formation is by a splitting of the original colony into as many parts as it con-

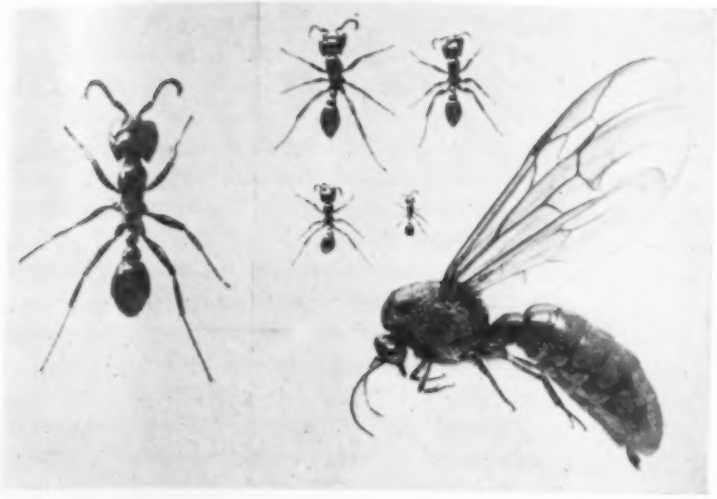


FIG. 59

Argentinian legionary (Doryline) ant *Eciton* (*Acamatus*) *strobeli*. Workers showing polymorphism and male, photographed to the same scale as the four smaller workers. (Photograph by Dr. Carlos Bruch.)

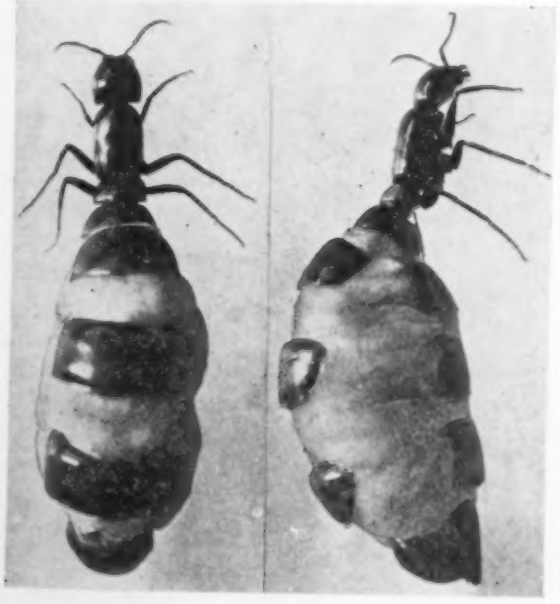


FIG. 60

Dorsal and lateral view of the wingless queen (dichthadiigyne) of *Eciton* (*Acamatus*) *strobeli*. Same scale as Fig. 59. (Photograph by Dr. Carlos Bruch.)

tains young queens. These huge, clumsy creatures (Fig. 60) are always wingless and must therefore be fecundated in the nest, and since the colonies, which comprise hundreds of thousands of workers, are nomadic and keep wandering from place to place, they must become independent entities as soon as they are formed.

We possess no accurate data on the age that ant colonies may attain. Some of them certainly persist for 30 or 40 years and probably even longer. In such old colonies the original queen has, of course, been replaced by successive generations of queens, that is, by her fertile daughters, grand-daughters and great-grand-daughters, and the worker personnel has been replaced at a more rapid rate, because the individual worker does not live more, and in most instances lives considerably less, than three or four years.

The feeding habits of ants are so varied and complicated that it will be advisable before considering them to describe the structure of the alimentary canal in both adult and larva. The mouth-parts of the adult are of the generalized vespine type and consist

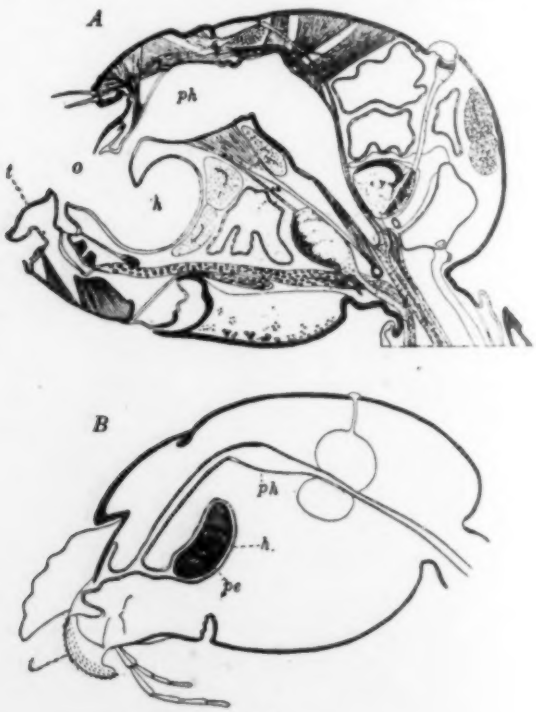


FIG. 61

Sagittal sections through the heads of ants. A, of queen *Lasius niger* with the mouth open (After Janet). B, of queen *Camponotus brutus* with the mouth closed. *t*, tongue; *o*, oral orifice; *ph*, pharynx; *h*, infrabuccal pocket; *pe*, pellet *in situ*, made up of solid particles of food refuse and strigil sweepings. Note stratification in the substance of the pellet, indicating successive meals or toilet operations.

of a small, flap-like upper lip, or labrum, a pair of strong, usually toothed mandibles, a pair of small maxillæ and a broad lower lip, or labium. The maxillæ and labium are each provided with a pair of jointed, sensory appendages, the palpi. The mandibles, which are really the ant's hands, vary greatly in shape in different genera and are used not only in securing the food but also in many other activities, such as digging in the earth or wood, transporting other ants or the young, fighting, leaping, etc. Liquids are, of course, merely imbibed and swallowed, but solid food is seized and crushed with the mandibles and the juices or smaller particles licked up with the tongue, which is a roughened pad at the tip of the lower lip (Fig. 61*t*) just anterior to the opening of the duct of the salivary glands. The small particles thus collected are carried back into a small chamber or sac, the infrabuccal pocket (Fig. 61*h*), which lies immediately below and anteriorly to the mouth-opening (*o*). This pocket is an important structure since it serves as a receptacle not only for the more solid particles of food but also for the dirt, fungus-spores, etc., which the ant collects during her toilet operations, for the ant is an exquisitely cleanly insect and devotes much of her leisure to licking and burnishing her own smooth or finely chiseled armor and that of her nest-mates. Moreover, the tip of the fore tibia is furnished with a beautiful comb or strigil which can be opposed to another comb on the concave inner surface of the fore metatarsus. The ant cleans her legs and antennæ by drawing them between these combs, which are then drawn across the mouth, with the result that any adhering dirt is carried off into the infrabuccal pocket. In this manner the dirt and the solid or semisolid food particles are combined and the whole mass moulded in the infrabuccal pocket into the form of a roundish oblong pellet (Fig. 61*B pe*). After any liquid which it may contain has been dissolved out and sucked back into the mouth, the pellet is cast out, so that no solid food actually enters the alimentary canal. All adult ants therefore subsist entirely on liquids.

The alimentary canal proper is a long tube extending through the body and divided into sections, each with its special function. The more anterior sections are the mouth cavity, the pharynx (Fig. 61 *ph*), which receives the ducts of certain glands, and the very long, slender gullet, which traverses the posterior part of the head, the whole thorax and the narrow waist, or pedicel of the abdomen as far as the base of its large, swollen portion, the gaster. Here the gullet expands into a thin-walled, distensible sac, the crop, which is used for the storage of the imbibed liquids. At its posterior end the crop is separated from the ellipsoidal stomach by a peculiar valvular constriction, the proventriculus. The hindermost sections of the alimentary tract are the intestine and

the large, pear-shaped rectum. The crop, proventriculus and stomach are the most interesting of these various organs. Forel calls the crop the "social stomach," because its liquid contents are in great part distributed by regurgitation to the other members of the colony and because only a small portion, which is permitted to pass back through the proventricular valve and enter the stomach, is absorbed and utilized by the individual ant. That the crop functions in the manner described can be readily demonstrated by permitting some pale yellow worker ant to gorge herself with syrup stained blue or red with an aniline dye. The ant's gaster will gradually become vividly colored as the crop expands. Now if the insect be allowed to return to the nest, other workers will come up to it, beg for food with rapidly vibrating antennæ and protrude their tongues, and very soon their crops, too, will become visible through the translucent gastric integument as they fill with the stained syrup. Then these workers in turn will distribute the food by regurgitation in the same manner till every member of the colony has at least a minute share of the blue or red cropful of the first worker.

The alimentary tract of the helpless, legless, soft-bodied ant grub or larva is much simpler than that of the adult. The mouth-parts are similar but more rudimentary. As a rule, the mandibles are less developed but in some larvæ they are strong, dentate and very sharp. The lower lip is fleshy and protrusible and provided with sensory papillæ instead of palpi, and the unpaired duct of the long, tubular and more or less branched salivary glands opens near its tip. The mouth-opening is broad and its lining in many species is provided with numerous transverse ridges beset with very minutes spinules (Fig. 62*C*). Larger, pointed projections or imbrications may also cover the basal portions of the mandibles. All these spinules and projections are probably used in triturating the food but perhaps when rubbed on one another they may also produce shrill sounds for the purpose of apprising the worker nurses of the hunger or discomfort of their charges. The gullet is long and very slender and opens directly into the large stomach, which throughout larval life is closed behind, that is, does not open into the intestine. A communication with the more posterior portion of the alimentary tract is not established till the larva is about to pupate. Then all the undigested food which has accumulated in the stomach since the very beginning of larval life is voided as a large black pellet, the meconium.

In the larvæ of the Pseudomyrminæ (Figs. 62, 63 and 64) there are certain very peculiar additional structures which may be briefly described. The head is not at the anterior end of the body as in other ant larvæ but pushed far back on the ventral surface so that it is surrounded by a great hood formed from the three thoracic

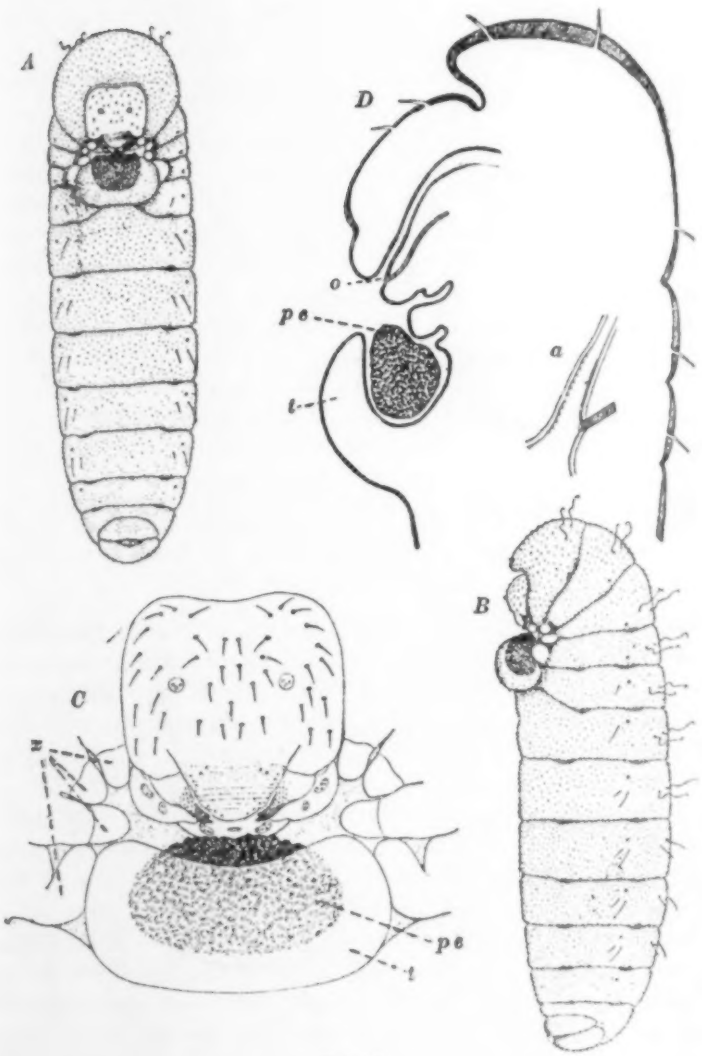


FIG. 62

Larva of *Pseudomyrma gracilis*. *A*, ventral; *B*, lateral view; *C*, head and adjacent portions of same enlarged; *D*, sagittal section through anterior portion of larva. *o*, oral orifice; *x*, exudatoria; *t*, trophothylax, or pocket, which holds the pellet; (*pe*), deposited by the worker nurses and which is eaten by the larva. Note the hooked dorsal hairs of the larva, which serve to suspend it from the walls of the nest. *a*, mouth cavity, more enlarged to show the fine spinules (also seen in *C*), which serve to triturate the pellet and probably also as a stridulatory organ.

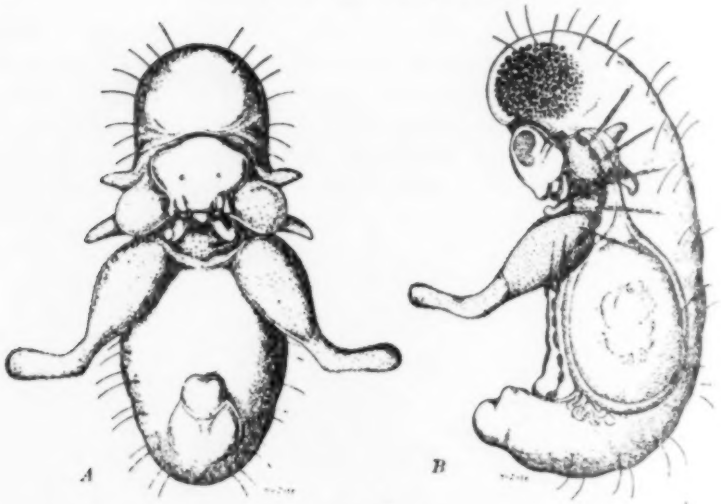


FIG. 63

A, ventral; *B*, lateral view of the first larval stage ("trophidium") of the Ethiopian *Pachysima latifrons*, showing the peculiar appendages ("exudatoria") surrounding the head. These belong to the three thoracic and the first abdominal segments.

segments, and the first abdominal segment, which lies immediately behind the head, has in the midventral line a singular pocket, the trophothylax (*t*). Furthermore, each side of this segment and each ventrolateral portion of the several thoracic segments is developed as a peculiar protuberance or appendage, which functions as a blood-gland, or exudatorium (*x*).

Unlike the adult ants the larvæ can devour solid food, though they are often fed, at least in their youngest stages, with liquids regurgitated on their mouths by the worker nurses. The larvæ of the Pseudomyrminæ are fed with the pellets (*pe*) from the infrabuccal pocket, which are placed by the workers in the trophothylax where they are within easy reach of the mandibles and can be gradually drawn into the mouth, triturated and swallowed. Some primitive ants (Ponerinæ, some Myrmicinæ, etc.) actually feed their young with pieces of insects or entire small insects, which are simply placed on the ventral surface of the larva within reach of its mouth-parts.

In a former lecture I referred to the fact that the larvæ of the social wasps, either before or after feeding, produce droplets of a sweet salivary secretion, which are eagerly imbibed by the adult wasps, and I designated this interchange of food between adult and larva as trophallaxis. I have recently made some observations which show that the ant larvæ also produce secretions which appeal to the appetites of their nurses. These secretions are more varied than in the wasps. Certain ant larvæ undoubtedly

supply their nurses with saliva, but many or all sweat a fatty secretion through the delicate general integument of the body, and the larval Pseudomyrminæ produce similar exudates from the papillæ or appendages above described. Although these various substances are produced in very small quantities they are of such qualities that they are eagerly sought by the adult ants. This explains much of the behavior which has been attributed to maternal affection on the part of the queen and the workers, such as the continual licking and fondling of the larvæ, the ferocity with which they are defended and the solicitude with which they are removed when the nest is disturbed. In other words, a decidedly egoistic appetite, and not a purely altruistic maternal anxiety for the welfare of the young constitutes the potent "drive" that initiates and sustains the intimate relations of the adult ants to the larvæ, just as the mutual regurgitation of food initiates and sustains the similar relations among the adult workers themselves.

I am convinced that trophallaxis will prove to be the key to an understanding not only of the behavior I have briefly outlined

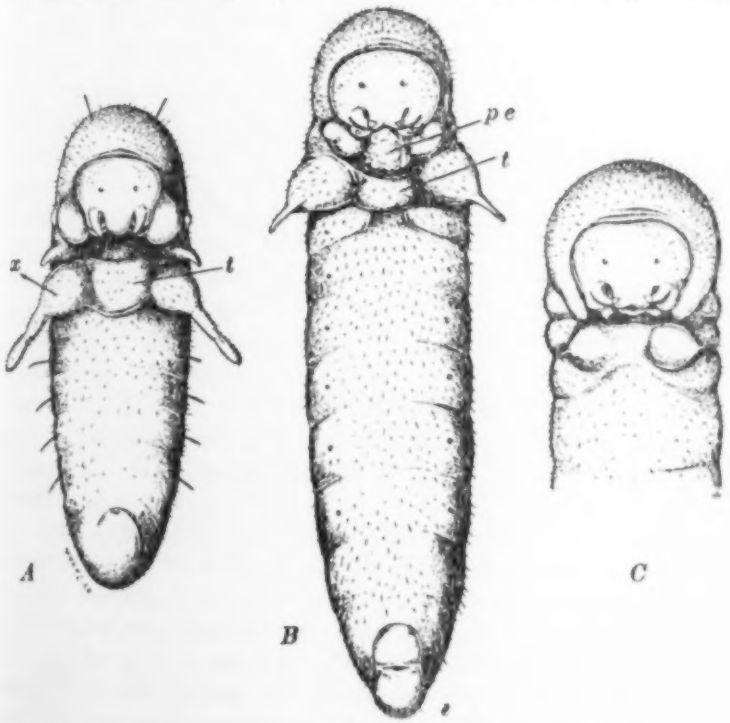


FIG. 64

Second, third and fourth (adult) larval stages of Pachysima latifrons, showing the gradual dwindling of the exudatoria. *A* and *B* show the trophothylax (*t*); and *B* also shows the food pellet *pe*; which is the pellet formed in the infrabuccal pocket of the worker nurse; *x*, exudatorium. See Figs. 62 and 63.

but also of the relations which ants have acquired to many kinds of alien organisms. In the accompanying diagram (Fig. 65) I have endeavored to indicate how trophallaxis, originally developed as a mutual trophic relation between the queen ant and her brood, has expanded with the growth of the colony, like an ever-widening vortex, till it involves, first, all the adults as well as the brood

Trophic Relations of Ants to Plants. Myrmecophytes
Trophic Relations of Ants to Insects outside the Nest.
Trophallaxis between Ants of Different Species.
Trophallaxis between Ants and True Guests.
Trophallaxis between Adult Ants.
Trophallaxis between Mother or Adult Workers and Larval Brood.
Mutual Regurgitation of Food
Symphily
Social Parasitism
Trophobiosis
Phytophily

FIG. 65
See text for explanation.

and therefore the entire colony; second, a great number of alien insects that have managed to get a foot-hold in the nest as scavengers, predators and parasites (symphiles); third, alien social insects, that is, other species of ants (social parasites); fourth alien insects that live outside the nest and are "milked" by the ants (trophobionts), and fifth, certain plants that are regularly visited or even inhabited by the ants (myrmecophytes). These extranidal relationships, represented by the two outer rings in the diagram are, of course, incomplete or one-sided, since the organisms which they represent are not fed but merely cared for or protected by the ants. In my next lecture I shall have more to say about some of these relationships.

(To be continued)

WATER[1]

By Professor LAWRENCE J. HENDERSON
HARVARD MEDICAL SCHOOL

THE task of science is one that may be fulfilled quite directly by providing useful information of a practical sort for our immediate needs, or it may furnish us with general ideas which, if we are skilful enough and intelligent enough, we may use to explain a great variety of phenomena. These general ideas when combined make up our conception of the universe. The latter function of science is the more important one. It is the one that brings science close to philosophy. It is the one that arouses the greatest interest and enthusiasm in those who pursue the task of science. When we look for generalizations of this kind we always seek simple explanations of nature, confident that they may be used as guides to our action in particular cases and as means for gaining an ever increasing control of the world that we live in. Everything in the history of science justifies us in saying that it is the general interpretation of nature which, especially in the last hundred years, has given man his extraordinary increase in material power, an increase in power which he has used far from wisely no doubt, but which for better or for worse he possesses.

In the ancient world there were a certain number of advances of this kind. The history of geometry, in spite of the labors of the last century and in spite of Einstein, is to a great extent ancient history. The few necessary general conceptions that the Greeks found out enabled them to develop a complete science of geometry, enabled them to be good surveyors, enabled them to begin to understand how to lay out the heavens and the earth in their astronomy and in their geography, enabled them to see how to make buildings, and to do a great many practical things.

But in the main the really important, the really general ideas of science, are modern, and of course the most interesting ones have to do, at least so most people will think, not with static things, not with space taken by itself, but with dynamic things, with the question of what is happening in the world. On the whole, the most interesting and the most important generalizations of science

[1] This lecture was one of the public series given in Boston on Sunday afternoons recently under the auspices of the Harvard Medical School.

will be judged by most men to be those that tell them what is happening in the world, how things happen and how those happenings may be, if possible, changed to their own advantage, and how they may be interpreted so as to yield a philosophy.

Of course everyone knows that the first step in this direction in modern times, the first step of great importance, was the interpretation of the phenomena of our solar system. It was the labors of Copernicus, of Galileo, and of Newton that enabled men to look at the sun and the moon and the planets, and to think quite clearly and quite simply and without any sort of difficulty at all about what their movements and their apparent changes in position and in form indicated. But, once more, it is not so much our solar system as it is our own earth that interests us, and until we come down to the earth and examine the happenings on the surface of the earth we are necessarily a long way from those things that interest us most.

How shall we state abstractly what is happening on the earth? That is one of the great questions for science as well as for philosophy, for sociology, and for all the other intellectual activities of man. What is happening on the earth? Of course there are an indefinite number of answers to that question; but if we seek the strictly scientific answer of physical science I think there can be very little doubt that it is possible to put it in a few words which make our interpretation of the changes in nature surrounding us surprisingly simpler than they otherwise would be.

Men in antiquity and in all ages have vaguely perceived an answer to this question. Perhaps many of you have heard of the famous remark of Thales, who is often thought of as the founder of philosophy and mathematics and science, that water is the origin of all things. This statement seems to many people to-day, I suppose, ridiculous, or at all events very exaggerated, but it is in fact much less ridiculous and much less exaggerated than you may suppose. A little later Empedocles and Aristotle, extending the elements from one to four, included water along with earth, air, and fire as the elements of which the world is made up. No doubt the word "element" is used in a sense a little different from our ordinary idea of an element to-day, but we still speak of the Aristotlean idea when we talk about exposure to the elements. Of these elements water is in many respects the most interesting. Nevertheless, while it was always clear in antiquity, as it has been in modern times, that water is very important in the world that surrounds us, its real importance is a comparatively recent discovery.

In the first place, it was only a century and a half ago when

Cavendish and Watt and others first found out that water is not itself what the chemist now calls an element, but that it is a compound, a compound of hydrogen with oxygen, a substance that can be formed by burning hydrogen gas in air or in oxygen. With this discovery a new road was opened, not only for chemistry and for physiology, but for the general interpretation of nature. Even before that time men had begun to understand the meteorological cycle, to perceive that there is going on on the earth a physical process which may be very briefly described as the evaporation of water from the ocean, from lakes and streams, and from the moist land, its dissemination as water vapor throughout the atmosphere by the winds, its precipitation as rain and snow and hail and dew, its collection into streams, but not a rapid collection, for it persists for long periods of time in the soil and underground, and finally its return to the ocean and reevaporation. That had been perceived, as I say, quite clearly before the discovery of the chemical nature of water.

After that discovery another thing became apparent, that all that is happening in living organisms, in animals, and in plants on the earth, may be regarded in one sense as a part of this great meteorological cycle, this great cycle of water in its evaporation and condensation and flowing back through definite channels; for, as you know, our rivers persist, our streams persist, the circulation takes place in a very definite and very definitely canalized way. As I say, when men had made out the chemical nature of water they were able to see that water and carbonic acid are taken up by the plant, taken, if you will, out of the meteorological cycle and built up into sugar and starch, and then, sooner or later, turned into a great variety of substances, the substance of the plant, in short. These in turn serve as the food of the herbivorous animals, of cattle and sheep, and they are not greatly modified when built up into the body of the ox or the sheep. Next they may be consumed by man, or by a carnivorous animal, and are made over into the materials of his body. But sooner or later they are turned out into inorganic nature, excreted, as water and carbonic acid, after being burned in the body, once more to become a part of the meteorological cycle.

That, I submit to you, is a fair statement, which no doubt needs a great deal of enlargement, a fair statement in terms of physics and chemistry, of what is happening on the surface of the earth. What is happening on the surface of the earth is, first of all, a circulation of water, a circulation of water which we recognize in the fall of rain, in the flow of streams, which we recognize equally in the growth of plants and in the feeding of animals on plants,

and in the burning up of material in the body of the animal—of course a circulation of water and of other things, other things which in the total are very numerous and certainly very difficult to know in all cases, but fundamentally a circulation of water.

I have not touched upon the energy of the process, the side of the question that is represented by the energy that goes into the water to evaporate it off the surface of the ocean, that goes into the green leaf to turn water and carbonic acid into sugar and starch, or the energy that comes out again in the form of muscular activity and body heat in you as you live, when you convert starch, sugar, and other things formed from them in the plant, back to water and carbonic acid. But let us say in the beginning that what is happening on the surface of the earth is this circulation of water, and let us add that it is a circulation which is driven by the energy of the sun, which is driven both in the one cycle, in the meteorological cycle, by the sun's heat evaporating the water, and in the other, the organic cycle, by the sun's energy making possible the formation of sugar and starch from water and carbonic acid.

In the first place, this process depends upon the great amount of water that there is on the earth. There is enough, if the earth had a perfectly smooth surface, to cover the whole earth, to a depth of two to three miles. How much of this is circulating it is very difficult to say. The amount is large. For instance, at the Equator evaporation takes off a layer of perhaps about seven feet every year from the tropical ocean. Of course the evaporation is less in other localities, and it is much less where there are no great bodies of water, but that will perhaps give you some idea of the magnitude of the process.

How much is the energy involved in this process? How much work is done? How much energy of the sun does it take to evaporate so much water? A few square miles of the tropical ocean are taking up solar energy in the process of the evaporation of water to such an extent that if that energy were available in the bodies of the people of the United States, it would run all their bodies; that is to say, all the work that we are capable of doing, plus all the heat that we produce, is equivalent to an amount of energy which is no greater than that involved in evaporating the water off a very few, perhaps ten, square miles of the surface of the tropical ocean. So you see that not only is there a vast amount of water being evaporated, but that amount of water carries with it, involves in its evaporation, a prodigious amount of energy.

Another way of studying the process is to try to form an idea of the run-off of the rivers of the earth. It has been estimated that the run-off is yearly, for all the rivers of the earth, about 6,500

cubic miles of water; that is to say, if you were to take a band a little more than two miles wide from Boston to San Francisco, and imagine it to rise up one mile into the air, that would give you a solid equivalent to the volume of water that pours back into the oceans yearly. And that of course is only a fraction of the water that evaporates yearly, because a great deal that evaporates and falls to the ground never reaches the ocean at all.

This prodigious amount of water carries with it to the ocean what seems to be an almost equally prodigious amount of other material. There are something like 5,000,000,000 tons of dissolved substance in the river waters going back to the ocean yearly, and nobody knows how much undissolved sediment there may be. This dissolved material has been leached out of the earth, it is being leached out of the earth all the time, and the record of it is the accumulation of dissolved substances in the ocean as well as that long continued action of sedimentation which is on the whole the greatest of geological processes.

In the sea, as a result of this, nearly all the chemical elements are contained in solution, most of them, to be sure, in such small amounts that they can not be measured, but so many of them are there that the sea water is quite a different thing from anything else in the world, and can not be imitated. Nobody ever made an artificial sea water that would serve the purposes of sea water as an environment for simple marine forms, as well as sea water itself. You may make as careful an analysis as you please of the sea water. You may put into pure distilled water all the things that you can find in the sea water, and then if you try to make organisms live there they will not live in it—some of them, at least, will not—as well as they will live in genuine sea water.

There is a good deal of resemblance between the salts dissolved in our blood and the salts dissolved in sea water. This has led Quinton to speculate about the use of sea water for medical purposes. He has made many experiments by diluting it to the proper degree and injecting it into the body. It has been suggested by Professor MacCallum that our blood is, so to speak, descended from sea water, that in the course of evolution somehow or other the fluids of the body originated as sea water. Of course single-celled organisms have no blood. When multi-cellular beings came into existence, where did the fluid which bathes the cells come from, provided multi-cellular individuals did develop from the uni-cellular? It is not a wild assumption to suppose that sea water furnished the inter-cellular liquid, that it was the material that first surrounded the several cells making up the complex organism. If you look into the whole story of comparative physiology that

idea, while it must not be pushed too far, seems not an extravagant one, and if so, it is interesting to reflect that in that original simple fluid, simple compared with our blood in most respects, there were nevertheless a vast number of substances that had been leached out of the earth's crust in the course of millions of years.

This peculiarity of sea water depends upon the fact that water is, among all the liquids that we know, on the whole the best solvent, the one that can dissolve the greatest number and the greatest variety of substances of all kinds. That of course is a statistical statement. There are some things that water can not dissolve which can be dissolved by a great many other things; but by and large, taking everything that we know, taking all the chemical substances that we know, there is not anything which on the whole is a better solvent, or capable of dissolving a larger number of things, or greater quantities of them, than water.

Well, that is one of the very decisive facts in the meteorological cycle. It is one of the great factors in determining the geological action of water, in determining a large part of the evolution of the surface of the earth. And, on the other hand, in the organic cycle, in men, in animals, and in plants, water, always present in large quantities—your own body is three quarters water—contains a great number of things dissolved in it. This solvent action is certainly no less important in physiology than it is in geology.

Not only does the water in your bodies, the water in the blood, the water inside the cells, the water in the lymph, contain a great many things dissolved in it, but it is almost exclusively in solution that things penetrate into your body. That of course may seem to you a strange statement. You are well aware that you eat many more or less solid substances—anybody can swallow a lump of sugar, which is certainly a solid—but in fact what is geometrically inside your body is not necessarily physiologically inside your body. The digestive tube is physiologically not inside the body, and the process of digestion turns most substances that are swallowed in solid form into soluble products, which are dissolved in water and then in solution pass the real physiological barrier, the wall of the intestine, and so enter the body. This is no less true of the substances that are excreted from the body. The waste products are turned out of the body in solution, and if it were not possible to turn them out in solution it is very difficult to imagine by what kind of physiological device it would be possible to carry on the activities of really active bodies and get rid of the waste products that have been burned up in the course of their activity.

This great circulation of water has another very important influence upon the world, and upon the world of life, and that is

its effect upon climate. Every one knows how much more steady is the state of the weather on small islands at great distances from continents than in most other places. Every one knows how much milder the climate is, how much cooler in summer and warmer in winter, at the sea shore than a comparatively small number of miles inland. This phenomenon depends upon water.

How does it depend upon water? What is the effect that water exerts in that respect? Well, there are several factors. In the first place, it takes a great deal of heat to raise the temperature of water, or, as the physicist says, the specific heat of water is high. If you take, for instance, a pound of water and a pound of almost anything else—there are a few substances that are harder to heat than water—and heat them over a carefully regulated flame for a certain length of time, and measure the rise in temperature, you will find that the rise in temperature of the water is less than that of the other substance. As I say, there are a few exceptions, but there are very few. The result is that an ocean or a lake absorbs heat, and does not itself rise very much in temperature.

Again, the evaporation of water takes up heat. Every one knows that. Every one knows that in order to evaporate water away at all rapidly you must heat it, and the amount of heat that is taken up in this evaporation of water is greater than in the evaporation of anything else; that is to say, you have got to put more heat into water in order to boil away or to evaporate, let us say, a pound of it, than you have in order to evaporate a pound of anything else. Thus the more rapid the evaporation the more effective the resistance of water to the rise of temperature, and for that reason the cooler the climate in the marine region compared with the climate in a region where there is no water to evaporate. This is one of the most important of all economic factors on the earth. It is a factor that, as much as any other one, perhaps, determines whether a given part of the earth is or is not really favorable for a high and active and prosperous civilization.

But these factors are no less important in your own body than they are in determining the climate. As you know, you are constantly producing a considerable amount of heat, and that heat has somehow or other to be got rid of. If it were not, your body temperature would continue to rise. Well, in the first place, if your body were not mostly water, and therefore such that it takes a great deal of heat to raise its temperature one degree, a little exercise might be impossible. If it were not for the fact that it takes so much heat to raise the temperature of the body a little, on account of the presence of water as its principal constituent, if it took only that amount of heat which is necessary upon the average

to raise the temperature of most substances one degree, running a mile might be quite sufficient to produce a coagulation of all the albuminous material in the body, and therefore death.

That is to say, the regulation of the temperature of the human body rests first of all upon this fact: that you have to heat water so much in order to raise its temperature a little, and then, in the second place, upon the effect of evaporation. The effect of evaporation is to cool the body very much, because you have to put a lot of heat into water in order to evaporate it, and since evaporation is the only way of cooling the body when the temperature of the environment rises to the temperature of the body this is a matter of the first importance, as everybody knows from his own experience in hot summer weather. It is a priceless advantage in the economy of your body that so much heat is taken up in the evaporation of water during sweating.

One of the factors that greatly influence the circulation of water on the earth is the way in which it clings in the soil. Indeed water clings better, on the whole, than any other substance. This is due to the phenomenon which everybody has heard of as capillarity, and which is well illustrated by the action of a sponge in soaking up water. If you study this process you will find that it is easy to represent the sticking power of a liquid in the soil or in any finely divided matter by the height to which it can rise in a small capillary tube, in a very fine tube. Water rises to a very great height relatively to other substances in such a tube, and for the same reason it sticks very tight in the soil and water rises to a great height in the soil. That is one reason why great portions of the earth are habitable, or at least can grow crops. If water did not stick as well as it does, a large portion of the fertile earth would be sterile.

But here again we have come upon a property of water which is just as important in the body as it is in the meteorological cycle. The living cell may be compared to a microscopic swamp, to a swamp of inconceivably fine dimensions. There is water running through it, and it consists of a very intricate meshwork of only partly known nature. In this swamp—this microscopic swamp, if I may call it that—these same forces, these same capillary forces, are of decisive importance. And here again it is the particularly great capillary activity of water that is one of the factors that determine the nature of physiological processes.

There is one more point that I want to refer to about the inorganic, the meteorological cycle, because it is a particularly interesting and important one, although this one seems to have no highly important direct bearing upon our own bodies and our own

life process. What causes rainfall? It takes a good many things to produce a precipitation of rain, but we may begin at the beginning and say that at least you can not have rain falling out of the air unless the air has become supersaturated with water vapor. The way to bring about that condition is to cool air that is pretty moist, because the amount of water vapor that the air can hold varies with the temperature. For instance, if you go down to the freezing point, to 32 degrees Fahrenheit, the amount of water vapor when the air is quite saturated is almost exactly one half of the amount of water vapor that is in the air at about 50 degrees Fahrenheit. Suppose, then, you have air that is three quarters saturated at 50 degrees Fahrenheit. Cool it down to 32 degrees Fahrenheit and it becomes not three quarters but three halves saturated; that it to say, it has 50 per cent. more water than it can hold. That water will come out in the form of rain.

This difference, a difference of 100 per cent. in the amount of water vapor that the air can hold, is far greater than the difference in the amount of the vapor of any other substance that the air can hold. That is to say, if you had any other substance at 50 degrees Fahrenheit, any other substance whatever, and the air were just three quarters saturated with it, and you cooled it down just to 32 degrees Fahrenheit, then you would not have reached the saturation point and the vapor would not fall out.

If there were not this property, rain would be a comparatively rare occurrence. Moreover, unless rain falls, unless water comes out of the air, there can not be further evaporation, because you can only evaporate into air which is more or less empty, so far as the water is concerned; that is to say, the whole meteorological cycle, the circulation of water, depends upon the rate of precipitation quite as much as upon the rate of evaporation, and the rate of precipitation of water is great because of this property of water.

I think I have perhaps said enough to make clear to you something of the natural importance of water. Such are the reasons why it is possible to say that what is happening on the earth in the last analysis is a circulation of water and the results of that circulation. This is true not merely because there is a great deal of water on the earth, but also because water is a remarkable substance that has a good many unique peculiarities. But in discussing these properties, I have thus far spoken only about what may be called the physical peculiarities of water. Water is quite as important a substance chemically, and indeed I think we may say that the most important clues that we find in the properties of water to our understanding of what is happening in our every day life are to be found in the chemical properties of water rather

than in its physical properties. This leads us back to the great French chemist Lavoisier, the most eminent victim of the French Revolution and the man who perhaps made the greatest contribution to science of the eighteenth century.

Lavoisier, studying the process of burning, of combustion, of oxidation as we call it, discovered that when things burn they combine with oxygen. Those of you who are not chemists and who have not studied chemistry will of course always feel a certain discomfort when one talks about the union of atoms. Atoms can not be seen. They are hard to imagine. But somehow or other the burning of tin for instance or the burning of mercury, is the combination of one or more atoms of the one element with one or more atoms of the other element. Tin and oxygen combine to form the oxide of tin. The atoms somehow or other fasten themselves together. That is what Lavoisier found out. He did not express it in terms of atoms, but he saw that these elements combined. So it is in the case of the burning of hydrogen, and water is a compound of hydrogen with oxygen. Atoms of hydrogen, two in number, combine with one atom of oxygen to form H_2O, according to our present way of stating the case.

Well, having discovered the nature of combustion, Lavoisier turned to all kinds of cases where there was combustion. He proved, for instance, with Laplace, the great astronomer, in one of the most remarkable collaborations in the history of science, that in the last analysis our life activity, so far as it is chemical, is oxidation. The oxygen that we breathe into our lungs is combined with the various elements that make up our foods, and then the products are turned out as carbonic acid gas, which is nothing but the oxide of carbon, the result of burning carbon, and water.

Then, reflecting further upon this, reflecting not only upon the chemistry of the process but also vaguely upon the energy that was involved, so far as it could be represented by the heat of the process, Lavoisier saw the real nature of the process, Lavoisier saw the real nature of the organic cycle and stated it clearly. He perceived that plants draw from the air that surrounds them and from the mineral kingdom the necessary materials of their organization; animals take from the plants that which the plant has formed, directly in the case of the herbivorous animals, indirectly in the case of the carnivorous animals, and build it up into their bodies, and finally the processes of combustion, fermentation, and putrefaction are continuously returning to the inorganic world the materials that were taken up originally by the plant. Of course

these materials are not merely water, nor merely water and carbon dioxide, but also other substances.

But note this. In the organic cycle water and carbon dioxide are free; the other things are fixed. Those things that are free in the physical sense are also free in the economic sense, under a wide variety of circumstances. You don't have to pay, at least in New England and in many parts of the world, for the water and carbon dioxide which are the principal foods of the plant; all that you have to pay for are the so-called fertilizers, which make up an infinitesimal fraction of the material taken up by the plant. Indeed, if it were not for the mobility of water and carbon dioxide in this cycle that Lavoisier first understood, there would be no vegetation on the mountain tops. How could the material get there? The mountain tops would necessarily be bare. Not only the mountain tops, but everything would be bare except the waters of the earth. It is because water and carbon dioxide circulate, circulate rapidly and penetrate everywhere and stick when they get there, that there is a widespread vegetation, that there is an intense organic activity on the earth.

But now what of this process that goes on in the plant? Lavoisier could not understand it. It goes on in the green leaf, and the green leaf is truly the symbol of life. It is the starting point of life. It is the factory in which are created the materials of your body and mine, of the body of every living thing. These materials are created by the conversion of water and carbonic acid gas into sugar and oxygen through the influence of solar energy and with the fixation of that energy. Sunshine, water and carbon dioxide, if one may speak very loosely, are the components in the green leaf from which sugar or starch and oxygen are produced. The oxygen is turned out—the oxygen, please note, that had combined previously in your body with hydrogen and carbon in the burning that is the essential process of your own activity. In the leaf this process is reversed. The energy of the sun is fixed in the leaf, and that is the source of the driving force of your body and of the driving force of every animal body.

And not only that, it is the source of our fuels generally. If you will reflect for a moment, and remember that not only wood, but coal and petroleum, gasoline, what you will that is combustible upon this earth, is stored solar energy that has been fixed in the green leaf in the past, you will realize the extraordinary economic importance of this process. You will then realize that the cycle is, in fact, not only from the standpoint of the material changes, but also from the standpoint of energy, of horse power, of what you

must buy and pay for as a source of any sort of material activity, the decisive factor on the earth.

Since we can increase this process of photosynthesis, since there are still portions of the earth that are not adequately utilized, it is conceivable that one of the solutions of the problem of the increasing demand for energy may be to grow more available energy, for example, in the Amazon basin, where there are forests that it does not pay to cut at the present time. We might, for instance, turn a vast amount of solar energy that is not being utilized at the present time, or that is being expended in a manner that we can not ourselves turn to account into starch and sugar, into industrial alcohol, and so get a substitute for gasoline. That is an idea that has been in the minds of chemists, of course, for many years. One does not know how economic conditions will develop. At all events, we have here the clue to an understanding of the sources of energy on the earth. Aside from the fixation of energy in the organic cycle, and aside from the water power and other sources of energy in the inorganic cycle, there is little enough of any kind of energy that is available.

You might perhaps have expected me to say something about water in medicine, since this is a medical school lecture. Water is indeed important in medicine, but not, I suspect, in a manner that makes it possible for a lecturer to explain in two words its importance. There are diseases involving water. Of course dropsy involves the physiology of water in a remarkable degree. And there are processes that might be regarded as in a certan sense the opposite of dropsy, such as the curious dehydration of sick babies. In many cases they lose water, and it is difficult, or impossible, to get it back again. I can only say that perhaps because these are in some respects simple phenomena—I say in some respects—we know just enough about them to know that they are so complicated that it is really difficult to explain them or even to understand them at all.

And so I shall, I fear, have to omit the more practical and immediate bearings of the physics and chemistry of water upon the organism, especially under pathological conditions. It is the principal constituent of our bodies, it is the principal substance that enters our bodies, it is the principal substance that leaves our bodies, and it is, as I have said, that substance whose movement in the inorganic world and in the organic world constitutes the first, the most fundamentally important, activity in the world that we live in.

INTELLIGENCE TESTS OF CERTAIN IMMIGRANT GROUPS

By Professor KIMBALL YOUNG
UNIVERSITY OF OREGON

THE influx of the foreigner into this country only became a serious problem with the shifting of the Old World source of the immigration from North to South Europe. The early situation in our national history was relatively simple. We had up to the Revolution, and forty years beyond, what constituted a genuine colonization. In fact, it was only after 1820 that a definite count was made of immigration. Even from this date until the Civil War, though the arrival of new-comers from Europe was constantly accelerated, the type of migration made for colonization of our free land and permanent citizenship.[1] In the two decades following the outbreak of the Civil War, the curve of yearly increase of immigration began to rise very rapidly, yet the source of the stream still remained Northern and Western Europe and the British Isles. The destination of this immigration, however, began to be more and more the rising industrial centers of our country and decreasingly so the rural districts—although it appears that the peasantry of Scandinavia and Germany often continued into the free lands of the Far West, the industrial workers of Great Britain, Germany and the bulk of the Irish went into the urban centers more particularly. Wherever this immigration went, it nevertheless fitted fairly readily into our socio-economic folkways and mores, and the biological amalgamation of the "Older Immigration," as it has been called, was in line with the racial stocks[2] already in the country.

[1] The existence of free land in America has had considerable influence upon our theories of government, our attitudes toward property, freedom and the socio-economic order generally. The significance of free land for racial amalgamation and cultural assimilation has been no less important, but less often noted.

[2] Race is used in this article in the popular rather than in the strict anthropological sense. Properly speaking there are no "races" in Europe, but only "sub-races." *Cf.* Retzius, "The So-Called North European Race of Mankind." *Jr. Roy. Anthrop. Institute*, 39: 277-313. *Cf.* also introductory chapter in Reuter, E. B., *The Mulatto* (1918) on use of term "race."

With the ever-increasing concentration of industrial controls and the accompanying specialization, and withal simplification of production processes due to the introduction of machine methods, the demand for cheaper, semi-skilled and unskilled labor became imperative. The rise of Germany to industrial power, the reaching of a point of stable population growth in Great Britain and the Scandinavian countries eliminated them as sources of this cheap labor. In consequence, we have a noteworthy change to the South and Southeast of Europe, and even to Western Asia, for this supply. In the short span of twenty years the shift in the center of gravity of the immigration to this country became the "common talk" of economics, sociology, political science and demography. The following table illustrates the now familiar facts:

TABLE I[a]

SHOWING THE SHIFT IN THE SOURCE OF IMMIGRATION TO THE UNITED STATES
(In terms of percentages of total from various sources)

Country	Year	Per cent.	Year	Per cent.	Year	Per cent.
Great Britain	1882	22.8	1907	8.8	1914	6.0
Germany	1882	31.7	1907	2.9	1914	3.0
Scandinavia	1882	13.3	1907	3.9	1914	2.0
Total Western European Countries	1882	71.3	1907	17.7	1914	.....
Italy	1882	4.1	1907	22.2	1914	26.5
Austro-Hungary	1882	3.7	1907	26.3	1914	25.6
Russian Empire	1882	2.7	1907	20.1	1914	23.0
Total Southeast and Eastern Europe	1882	18.2	1907	75.5	1914	75.6

The complete significance of this change in the source of our immigration we do not yet know. If the theory of General F. A. Walker be true, we may doubt whether immigration has been as important or necessary for the growth of the country, since 1850 anyway, as some persons imagine. Had we had no immigration from the middle of the last century on, according to Walker, our present population would be as large as it is to-day, but racially we should be a much more homogeneous people, or, at least, in the way of becoming so.

Now the meaning of the coming of the "New Immigration," as that from Southern Europe has been called, in the matter of racial mixture is an unknown quantity. The writer believes, however, that there is accumulating evidence from studies in general

[a] Table compiled from Ellwood, C. A., *Modern Social Problems* (1913) and reports of immigration. The term "Russian Empire" in the table included Russian Poland and other sections now cut away from the former empire. Racially most of the contribution from Russia was Hebraic or Polish rather than strictly Russian.

intelligence of certain immigrant groups, at least, which material, coupled with the results of researches in the inheritance of mental traits, should cause us to consider rather carefully the bearing which these facts may have on features of the racial mixture that will surely come out of the shift in the source and nature of immigration.[4]

The present paper will deal specifically with certain samples of the South European immigration in terms of general intelligence. The special question is: Leaving aside physical characteristics, differences in emotional traits and cultural contacts, what are the significant findings of psychology concerning the general intelligence of certain of these immigrant groups that have come to us so overwhelmingly in the past thirty years?

The nature of general intelligence need not detain us here. The uninformed should refer to the long series of important studies upon this question initiated by Binet in France, and expanded by Stern and his pupils in Germany, and particularly by Goddard, Terman, Thorndike and Yerkes in the United States, and more recently still taken up by a group of English psychologists—Webb, Burt, Hart and others. There are obviously several problems as to the exact nature of so-called general intelligence, its growth, its importance in successful life career, and especially as to its inateness (that is *in potentia*). On the latter point, the evidence at hand seems sufficiently valid to establish that general as well as specific abilities are transmitted by heredity. The precise biological nature of the units involved we do not yet know. Special talents may actually turn out to be due to the presence of separate units in the germ plasm, and all-around ability may be due to a conflux of several factors—multiple and difficult to segregate in the chromosomes. Whether in fact, general intelligence is shown to be simply a convergence of special traits in certain patterns, as Thorndike might assume, or whether due to a more general factor as Spearman seems to hold is unimportant for our present paper. Though the entire data on the mechanism of inheritance are not at hand, and even admitting that the subtle influences of environment have not always been completely segregated and controlled in the studies made, the writer believes that our social programs for education, Americanization, amalgamation of the foreigner racially, can not nonchalantly ignore these important implications.

[4] Studies of the second and third generation of certain immigrant stocks are beginning to accumulate, but so far we lack psychological measures of the mental capacity of these various generations,—more especially of the strains that have gone into the mixtures. The writer, however, is in much sympathy with such studies as Drachsler's and others.

The studies of Galton, Woods, Pearson, Davenport, Thorndike, Earle, Starch, and others revealing the inheritance of intellectual traits appear reliable enough, irrespective of the peculiar biological form which subsequent research may reveal, to make the present status of the mentality of immigrant groups, if known, rather prognostic, to say the least, of what the mentality of the future generations of these peoples will be. In other words, the evidence appears rather conclusive for the inheritance of mental abilities, and if general intelligence tests reveal a given level of intelligence in an immigrant group may we not assume that we can predict something of the mental endowment which such a group will add to the future mixtures with other racial groups?

It is well recognized by all persons interested in racial mentality and has been recently reiterated by Major Leonard Darwin[5] that what we want is a high average intelligence in the masses, not a small group of selected superior intelligences, with the bulk of the population of low or inferior intelligence. Out of the constantly changing matrix of a high average intelligence will arise the superior-minded persons who will be able to make the outstanding cultural contributions of the future, while the good average mentality of the masses makes for solid citizenship, appreciation of high cultural values and successful group spirit. Any mixture which will lower the level of intelligence of a group and restrict the variability of the same will be deleterious. For instance, if the average intelligence of certain of the South European stocks which have come to us in the past twenty-five years should prove to be as high as that of the older American stock (i. e., of North European ancestry) the problem of mixing the older and the newer stocks, so far as general intelligence is concerned, will not be serious. However, on the other hand, if the Latins, say, who come to us should prove to be but four fifths as intelligent on the average and less variable when compared with the North European offspring in this country, the racial mixture between the two may be damaging to the welfare of the country.

With the methods of testing general intelligence that have come out of psychological investigation and with the implication of heredity in mental endowment, let us review the significant studies which throw light on the matter of immigrant mentality. On the basis of these we may then be able to note certain important bearings of these findings on the problem of immigration as it relates to racial mixture and the general intelligence of our future population.

[5] Darwin, L., "The Field of Eugenic Reform." THE SCIENTIFIC MONTHLY, 13: 392.

The writer will review three or four studies made during the past five years which deal with racial stocks in various parts of this country and will then add notes on his own contribution which grew out of a rather extended investigation of certain South European groups in California.

In one chapter of the published data from the psychological testing of men in the army[6] is shown the relative standing in the mental tests of the foreign-born men of various nationalities found in that portion of the army which was tested. Each man tested in the army was given a final letter rating ranging from A to E depending upon his raw score in either the alpha, beta or individual test. The alpha, as is now well-known, was devised for literates of ten years mental age and above, the beta was devised primarily for men of low-grade mentality, but was also used for illiterates or for men who did not understand the English language well enough to handle alpha. The individual tests were exclusively used for low-grade mentalities who did not score well or at all in the group tests (alpha and beta.) The men of high mentality were given ratings of A and B. Men in these classes were considered, other things being equal, as being prospective officer material. Grades C and D made up men of the grades of privates, but those of D rating were discovered to be rather poor military "risks," to borrow a term from insurance practice.

The following nationality groups are selected as samples from a longer list showing the rank order of countries according to the percentage of men in each nationality group receiving their final letter ratings in D, D—, and E, and also in A and B.

TABLE II[7]

SHOWING THE PERCENTAGE OF MEN OF SAMPLE NATIONALITIES RECEIVING FINAL LETTER RATINGS UNDER THE GIVEN CLASSIFICATIONS

Nationality	Per cent. D, D— and E	Per cent. A and B
Total White Draft	24.1	12.1
All Foreign Countries	45.6	4.0
England	8.7	19.7
Germany	15.0	8.3
Sweden	19.4	4.3
Austria	37.5	3.4
Ireland	39.4	4.1
Russia	60.4	2.7
Italy	63.4	.8
Poland	69.9	.5

[6] *Memoirs of the National Academy of Sciences*, 15. *Psychological Examining in the United States Army*, Pt. III, pp. 693-700.

[7] *op. cit.* p. 696: The omitted nationality groups fall variously in the range of the percentages given in this table. The totals for the white draft and for the total foreign nationalities are given for comparison.

In general the superiority of the Nordic stocks over the others is evident in this table. No assertions of language handicap can be brought against these findings, for the men who were unable to manipulate the verbal test, alpha, were given the performance test, beta, or the individual performance tests. Over 85 per cent. of the Italian group, more than 80 per cent. of the Polish group and 75 per cent. of the Greeks received their final letter grades from the beta or other performance examinations. The corresponding percentages for the Northwestern Europeans were: for the English, about 8 per cent, for the Germans slightly over 30 per cent., for the Swedish about 58 per cent.

It is interesting to compare these figures with those compiled for the Southern and Northern negro draftees: 82.1 per cent. of the former received final letter ratings of D grade or lower; for the latter the like percentage was 47.2. It will be enlightening to recall these comparisons of the negro draft with the Italians and others when reference is made to Miss Murdoch's investigation.

Dickson[8] in his study of first grade school children in certain public schools in California, while his number of cases was small, found important differences in the intelligence quotients of the various groups when tabulated under racial stocks. A summary of his data follows:

TABLE III

SHOWING DIFFERENCES IN INTELLIGENCE QUOTIENTS IN FIRST GRADERS BY RACIAL STOCK

Race	No. of cases	Median I.Q.
Spanish	37	78
Portuguese	23	84
Italian (chiefly Southern Italy)	25	84
North-European born	14	105
American (North-European ancestry)	49	106

With the average intelligence as measured by careful Binet tests revealing such differences in children of the first grade (the children were practically all of the same chronological age) would not the educability, the future economic success, and the contributions to national culture and well-being be differentially in favor of those of higher intelligence? True, the overlapping in such groups is considerable. The figures do not mean that *all* the Spanish do but four fifths as well as the children of North European stock. Some of the Spanish children have intelligence quotients above the average of the latter groups, but, on the other hand, the lower quotients of the Spanish group fall below the quotient of the lowest American child. So, too, the Portuguese and Italian groups over-

[8] V. Dickson, Unpublished Ph.D. thesis (Stanford, 1919), Tables from notes of Dr. L. M. Terman. Dickson's study will soon be off the press.

lap the other groups greatly. It must never be ignored that in dealing with averages in intelligence tests, the matter of variability must also be taken into account.[9]

The objection might well be raised that the differences in these racial groups found by Dickson are due to accident of environment which would be eliminated later. Would not, for example, school contacts wipe out, in large part, these differences? Might not home influences, such as use of the foreign tongue by parents and children, affect the standing of the Latin children in these tests?

With a view to investigating these and allied questions, Miss Thomson[10] five years later undertook the re-testing with Binet tests of the same children whom Dickson examined. In a period five eighths the total length of time demanded by our elementary public school curriculum one would imagine that any grave handicaps of language or family background would be largely overcome. After correcting Dickson's tables on the basis of chance errors in chronological age in his group, and eliminating, of course, from her group the cases which could not be found for re-testing, she presents the following table:

TABLE IV

SHOWING THE CHANGE IN MEDIAN I. Q. IN FIVE YEARS FOR RACIAL GROUPS

Race	1916 median I. Q.	1920 median I. Q.
Total South European	88.0	85.5
Portuguese	88.3	74.0
Americans (from one school)	111.0	110.5
Americans (from second school)	102.3	95.0

In another table somewhat differently arranged showing the ancestry of the pupils she gives the following from her own data:

TABLE V

SHOWING THE MEDIAN I. Q. OF CERTAIN RACIAL GROUPS IN PUBLIC SCHOOLS

Race	Median I. Q.	Range of I. Q.
South European	81.0	51 to 117.5
North European born	97.5	79 to 114.0
American born (North European ancestry)	102.0	62 to 139.9

While the number of cases is small for wide conclusions, it is apparent that the American group not only has the highest median

[9] It is unfortunate that the P. E.'s of these distributions were not at hand.

[10] Thomson, Mildred, "Validity of Stanford-Binet Tests as a Basis of Prediction of School Success" (A.M. thesis—Stanford University, 1920—unpublished). It must be noted that Miss Thomson was unable to secure more than two-thirds of the same children as Dickson tested, but there is no reason for believing this reduction in the number of cases was due to anything other than chance. Speaking in terms of intelligence, there is as much likelihood of an American family moving away as a foreign one.

I. Q., but that it is the most variable in range of I. Q. Miss Thomson notes:

> It seems that as a whole the tests are as accurate a judgment of the mental capacity of the low foreign element as of the American children . . .

As to the matter of the alleged language handicap of the children of foreign parentage she comments:

> Had language difficulty caused the first low median, the central tendency to change would now be plus. (That is, the overcoming of the language handicap by additional years in school would raise the median I. Q.) . . . . It seems evident that although the tests involve the use and understanding of language, low scores result not from the failure to understand, but from the failure to comprehend.

Miss Murdoch[11] has studied four racial groups in certain public schools in New York City in order to discover any mental differences in these groups with special reference to light on the problem of Americanization. Her groups included Hebrew, Italian, "American" and negro boys in the upper grades. The children all understood English, the Italian group being especially hand-picked, that is to say, only the boys who in the opinion of the school authorities did not suffer from any language handicap were tested. Miss Murdoch believes this selection of Italians was in favor of the brighter boys in this nationality. The children were not selected by age, but by grade, ranging from the fifth to eighth, inclusive, which means that the age groups ten, eleven, twelve and thirteen were most frequently represented. This grade selection, however, eliminated from the comparison all the pupils ten, eleven, twelve and thirteen who were still in the lower grades. This means that the selection was likely in favor of the more intelligent pupils of these age groups. The groups came from two different sections of New York City, both described as rather "undesirable." The writer of this article says:

> At least, between Jewish and Italian boys and between white and colored boys respectively, no allowance for difference in neighborhood environment need be made.

The test used was devised by Pressey along the lines of the army alpha. Close to 500 cases each of Jewish, American, and Italian boys and 225 negro boys were examined. The Hebrew and American children had practically the same averages in the tests. The Italians and negroes while running somewhat together, with the latter slightly better, were decidedly inferior to the other two groups as measured by these tests. Taking the twelve-year-olds

[11] Murdoch, K., "A Study of Race Differences in New York City." *School and Society*, 11 (1920): 147-50.

who were tested as a sample—in the Italian group 13.5 per cent. equal or exceed the 50th percentile or median of the Jewish boys; 24 per cent. of the negroes exceed the median of the Jewish; and 50 per cent. of the Americans likewise. For the three age-groups having the largest numbers in the total group studied, i. e., the eleven, twelve, and thirteen-year-olds—the average is 15.5 per cent. for the Italians, 30.5 per cent. for the negroes, 53.7 per cent. for the "Americans" equaling or exceeding the median for the Hebrews.[12]

Whether the children studied according to age in relation to test results, or by grade location the Italians maintained "their position at the foot of the four races." Language can not account for the low scores of the Italian, for, as already noted, those who were suffering from difficulties with the English language were excused from the tests. Miss Murdoch writes:

> The fact remains that Italians who were thought by their teachers, principal, and the neighborhood social workers to be laboring under no language handicap were found to be very inferior to the other three races.

However, since the test used by Miss Murdoch was based upon verbal concepts, in part at least, the accusation may still be made that the Italian home does not furnish the English tools to its children so well as the Hebrew, negro, or American. Let us look further to see what additional studies have shown.

In order to test the matter of alleged language handicap and to investigate the general question of mental differences in immigrant groups in this country, the writer of the present article undertook in the years 1919 and 1920 to apply psychological tests to the children of certain South European and Latin American immigrants—viz.: South Italians, Portuguese, and Spanish-Mexicans—and to compare the same with groups of children of Northern and Western European ancestry.[13] Over 90 per cent. of the Latin stock (as we may call the former for brevity) studied were born in this country and practically all of the children of the latter stocks, or Non-Latin as they have been called. The survey was made in several cities and towns of the west-central portion of the state of California.

Several measures of mental differences, direct and indirect, were made. Such outside criteria as the grade location, teachers'

[12] The number of negroes at these ages is too small to warrant any wide conclusion concerning the intelligence of negroes compared with Italians. The negroes were a much more highly selected group perhaps than the Italians, further, the Northern negro is on the average higher than the average intelligence of the entire race in this country.

[13] This study will be published soon in *The University of Oregon Publications* under the title: "Mental Differences in Certain Immigrant Groups."

estimates of intelligence and of the quality of schoolwork were made and compared with the results of the psychological tests themselves. Of the latter there were two batteries of so-called general intelligence tests: the first, the army alpha, is a verbal test based quite extensively upon language and dealing with concepts of verbal nature; the other, a slightly modified army beta, adapted to school children who understand at least a modicum of English necessary for instructions. Rather than selecting the school children from certain grades the writer selected all the twelve-year-old children in the schools which avoided the biased sampling that must have arisen had children in one or two grades only been selected. By this method, then, all the twelve-year-olds from the entire public school systems in the communities surveyed were studied irrespective of their grade location. Incidentally the manner in which these twelve-year-olds distributed themselves through the grades indicates once again the fact that chronological age is no criterion to the pedagogical age of a child, of whatever racial stock.

This is no place for a detailed report of the findings in this study, but the pertinent facts for the problem of immigrant mentality will be briefly given. It was found that the actual grade location of the children is the best single criterion of their intelligence aside from the mental tests themselves. The comparative standings of the Latin with the non-Latin groups shows that the modal grade for the latter is the low seventh, for the South Italians, the high fifth, for the Spanish-Mexicans, the high fourth, for the Portuguese, the fifth.[14] On the basis of the teachers' estimates of general intelligence on a seven-rank scale the Italians are on the average .8 of one class-rank below the "Americans," the Portuguese are over one class-rank below the latter, and the Spanish-Mexicans over one and one quarter class-ranks below.

Coming directly to the results of the tests themselves, the important fact for us is that of overlapping of intelligence in the groups. The following tables give first the absolute differences as measured by the tests, then the measurement of the overlapping:

TABLE VI

(A)

SHOWING THE DIFFERENCES IN AVERAGES AND IN VARIABILITY IN GROUPS

Race group	Median Alpha	P. E. dist.	Median Beta	P. E. dist.
"American"	59.21	18.48	68.88	7.03
Italian	24.92	13.90	54.75	10.90
Portuguese	22.00	15.65	52.03	9.88
Spanish-Mexican	23.67	12.82	52.96	10.76

[14] The Portuguese group was not segregatable into half grades.

(B) ALPHA RESULTS

SHOWING PERCENTAGES OF FOLLOWING RACIAL GROUPS EXCEEDING THE QUARTILES OF THE AMERICAN GROUP (Actual and theoretical)[15]

Race group	Per cent. exceed. American Q1 (Actual)	(Theor.)	Per cent. exceed. American Median (Actual)	(Theor.)	Per cent. exceed. American Q3 (Actual)	(Theor.)
Italian	24.50	22.66	7.00	4.95	1.00	.55
Portuguese	22.50	23.88	10.00	6.55	2.00	1.07
Spanish-Mexican	21.50	17.36	6.80	2.81	.75	.20
(C) BETA RESULTS (as under B)						
Italian	33.40	31.21	18.00	16.11	8.25	6.94
Portuguese	29.00	25.46	13.75	11.51	4.15	4.09
Spanish-Mexican	30.40	27.76	15.50	13.79	6.40	5.59

From the average for the American twelve-year-olds it looks at once as though measured by the alpha the Latins are decidedly inferior to the Americans. The beta averages, while more nearly alike for the Latins and Americans, still show a marked superiority for the latter. It must be noted that the range of the beta units is just half that of the alpha, hence the differences in the actual figures in the table are not indicative of the real differences revealed. It is still true, however, that the Latins approach their competitors more closely in the beta than in the alpha tests. The latter is based, as we noted, upon verbal concepts, while the latter is a so-called performance test operated independently of language. Were it not for the differences shown in other measures of intelligence, as, for instance, grade location, teachers' estimates of intelligence, and school marks, it might be imagined that the differences brought out in beta are more truly significant of the differences in ability than alpha. I have shown elsewhere that this is not the case,[16] but space prevents a lengthy discussion of the matter here. The following points summarize these facts:

First, the beta tests proved too easy for the American twelve-year-olds who were above their years in intelligence. This means that the tests were not diagnostic enough for these children and that there was a piling up of high scores for these children at the upper end of the scale. This narrowing of the spread of their actual abilities is the reason for the lower P.E. of the Americans in beta as compared with the Latins. Had the tests been more suited to their real mental capacities, some of them would have scored higher and the average for their group would have risen, and their variability as a group would have been greater. For the Latins the tests proved well suited for their capacities.

[15] The figures tabulated under "theoretical" are the computed measures of overlapping when the reliability of the tests are known. *Cf.* Kelley, T. L., "The Measurement of Overlapping." *Jr. Educ. Psychol.*, 10: 458ff.

[16] Discussed in writer's study mentioned in footnote No. 13 above.

Second, checking the alpha by correlation against the outside criteria, such as, grade location, teachers' estimates of intelligence, and the school marks, it was found that the alpha, the verbal test, was more diagnostic of the mentality and hence educability of the Latins and the Americans both than was the beta. In addition these correlations go to indicate that the asserted language handicap under which the foreign children are supposed to labor does not exist, at least so extensively as imagined.[17] As Miss Thomson put it the failure in the tests and in school is not based so much on failure to understand as failure to comprehend.

The measures of overlapping (sections B and C of above table) reveal more significant facts of mental differences in these groups than the differences in average score. If these tests are at all true measures of differences, and there is certainly much evidence that they constitute the best measure of mentality science has yet produced, may we not assume that the extent of the overlapping among the groups clearly concerns an important problem before us, namely: the relation of these differences to future racial mixture which is subsequent to our enormous immigration? If there is anything preponderant in mental heredity it appears that this question must be answered.

Taking the South Italian group as a sample of the Latins and near Latins (as we may term the Spanish-Mexicans),—if they equalled the American group, 75 per cent. of them should exceed the first quartile or 25 per cent. of the latter. As a matter of fact in alpha less than 25 per cent. of them exceed the lowest 25 per cent. of the Americans. So, too, with the median or second quartile, but 7 per cent. of the South Italians exceed the lower 50 per cent. of the Americans, and but 1 per cent. exceed the upper 25 per cent. of the latter.

It may be that alpha is unjust to the Latins even though there is considerable evidence that it is on the whole quite adequate for diagnosis of mental differences. It may even be that the language difficulty which a proportion of the Latins certainly had when they entered the public school has persisted until its effects are

[17] It is rather interesting to recall that thirteen years ago Ayres in his book, *Laggards in Our Schools*, pointed out that language difficulty did not operate as a factor in school retardation. He wrote: "Wherever studies have been made of the progress of children through the grades, it has been found that ignorance of the English language does not constitute a serious handicap." (p. 116). Of course no one would argue that in children newly arrived in this country from foreign countries speaking another language would not be handicapped in the period of acquiring our tongue. But beyond that period, the trouble in retardation lies in other directions.

felt as late as five or six years after entry.[18] Therefore for those who would still maintain that alpha is too distinctly advantageous to American children, the overlapping in beta, in spite of the fact that the evidence is clear that this test is unfair to the American twelve-year-olds, still shows the latter superior. But 33 per cent. of the Italians exceed the lowest 25 per cent. of the Americans, but 18 per cent. exceed the lower 50 per cent. and but slightly over 8 per cent. the upper 25 per cent. There is no evidence that the beta was in any way unfair to the Latins either in content or presentation. All the children were tested by the writer personally in small groups and in each session members of all the racial stocks were present. The Portuguese and the Spanish-Mexicans compare less favorably with the Americans than the South Italians.

We may now conveniently summarize the results of the experimental findings on this subject before passing to interpretative paragraphs.

The army tests on recruits and draftees showed that the Latins and other Southern European (also certain Eastern European) groups were decidedly inferior to the men who were natives of Northern and Northwestern Europe. The Dickson-Thomson studies have presented good evidence that the intelligence of the racial groups, at least of those investigated, does not improve by education, and further that in the samples which they study the Latin groups are on the average eight tenths (.8) the average intelligence of the American children of North European ancestry. Murdoch's survey revealed that as measured by the Pressey scale of general intelligence, the Italian groups which she studied were decidedly inferior to the American and Hebrew children tested, and even slightly lower than the negro children measured at the same time. Her twelve-year-old group (which we noted was a selected sample) compares quite noticeably with the writer's. In her results she reports that 13.5 per cent. of the Italians equaled or exceeded the median of the Americans. The writer's figure for a similar measurement of overlapping was but 7 per cent., but the difference may be due partly to the nature of the test and partly to the fact that his sample was not at all handpicked. It may be due to actual differences in the intelligence of the group. The important point, however, is the likeness of the two studies.

[18] The writer in answering those who maintain that all differences in mentality (barring the extreme feeble-minded) are due to environment and opportunity, is always puzzled to know how these persons account for the distribution of children at 12 years of age, some in third, fourth, fifth, sixth and seventh grades, when they all started in school at the same time.

One may use norms which were developed[19] for translating the alpha scores of school children into Binet mental ages. If this is done it is found that the Latins measured are on the average two years retarded as compared with the American groups studied. Again the caution must be repeated that the range of scores in each group is wide, meaning that the differences are relative not absolute.

Space forbids further comment on the studies themselves, but we must turn before concluding to a few paragraphs on the probable bearing of these findings upon the problem of immigration and the mixture of immigrant stocks in this country.

If the researches into mental heredity have the validity which we suspect, then the differences shown in these investigations just cited are simply reflections of what is found in the general adult population. The findings of racial differences in immigrant stocks revealed in the army lend weight to this assumption. Further it is interesting that the preliminary testing of the Japanese and Chinese made in California indicates that these Oriental immigrant stocks compare very favorably with the American population of North European ancestry in the same neighborhoods. Surely the language handicap is of greater potency in the Oriental than in the European. So it seems that these methods of testing have enough pertinence to make us pause and consider the meaning of their findings.

As noted at the outset of this paper, we have shifted the source of our immigration from North to South and East Europe, and further we have drawn more and more upon a low type of peasantry as compared with the rather good average industrial and agricultural classes that formerly came to us from German, Scandinavian and Anglo-Saxon countries.

As we noted above[20] the problem of mixing racial stocks is one of producing high average intelligence in the masses so as to lay the biological chances for the production of each generation of the superior persons who will make the greatest advances for their generation. If the mentality of the South Europeans who are flooding this country is typified by the mentality of the three groups studied by the writer and others, the problem of future standard of living, high grade citizenship and cultural progress is serious. The writer does not attempt to say whether these findings are

[19] From norms developed by Drs. S. C. Kohs and W. M. Proctor at Stanford University (1918-19). *Cf.* Proctor, W. M., "Psychological Tests and Guidance of High School Pupils." *Jr. Educ. Research*, Monog. 1, No. 1, pp. 70 (1921).

[20] *supra*, p. 5.

typical of the entire racial groups from which these samples came. None of these studies is an investigation of the whole population of Portugal, South Italy, Spain or Mexico. They are surveys of these stocks as actually found in the usual immigrant settlements in this county. However, the writer stands firmly upon the ground that the evidence points to the fact that these samples are *very typical of the immigrants who reach this country* from these European sources. Is not this after all the *significant thing?* For instance 85 per cent. of the total immigration from Italy in the past 30 years has been from the same districts of South Italy from which the largest sample of the writer's own investigation and that of Mr. Dickson and Miss Thomson came. The indirect evidence is that Miss Murdoch's Italian subjects were also from South rather than North Italy. In fact it is not impossible that the Italian in California is even a little superior on the average to his confrère who has neither energy nor ambition to get out of the industrial centers where most of these people first settle in our country. Of the Portuguese the writer can only venture a guess that he is much like the Portuguese found elsewhere in the United States, principally in New England. The Spanish-Mexican groups appear typical of the immigrants of this stock.

Does not the evidence accumulating, one phase of which has been reviewed here, point conclusively to the fact that a continued deluge of this country of the weaker stocks of Europe will ultimately affect the average intelligence of the population of this country? It is comment everywhere that the better stocks are losing ground compared with the poorer in the matter of offspring. The more intelligent classes are practicing, in one way or another, a conscious control of the number of their children. The result of this must mean a shifting in the average intelligence of the population toward that of the poorer stocks. Now hybridization of stocks is already taking place. It does not seem to be true that the inferior stocks always mix with their own kind—the history of the Kallikaks and such like proves that these stocks are constantly sending out their tenacles into the higher biological strains. Have we not been caught in the myth of the Melting Pot and in a sort of pious wish that all was well and that nothing could happen to us? The general economic progress of the past fifty years may have made us myopic of the larger meaning of these accompanying changes in our population. As Irving Fisher put it:[21]

> Mechanical inventions . . . have given us more and more room for expansion and we have mistaken this progressive conquest of nature for a progressive improvement in ourselves.

[21] Fisher, I.: "Impending Problems of Eugenics." THE SCIENTIFIC MONTHLY, 13: 215.

Certain sentimentalists have talked glibly of *assimilation* of racial stocks. This presupposes the capacity of one stock completely to take over another and make as the original stock was. There may be cultural assimilation (even this is doubtful in a technical sense), but there can not be biological assimilation. What we have is amalgamation, and as Conklin and others have pointed out, amalgamation means a hybrid stock, a stock compounded out of the elements of the two or more strains running into the new generation.

It is true that biologically the mixing of the North and South European is hardly analogous to the mixing say of the white and the black races or the whites and the mongoloids. Biologically as previously noted[22] the European stocks are actually sub-races. Furthermore in reference at least to the latter stocks the problem is not an *all or none* principle. If these tests of general intelligence are at all significant it is evident at once that there is considerable overlapping in the various groups. For the future of this country a careful selection of the best in all the European stocks might be thought desirable. However, it is a common assumption of breeders and eugenists that for the production of a stable, homogeneous, strong stock isolation, group inbreeding and some occasional, but not too great, influx of exotic strains is necessary.[23] The incoming of even somewhat distinct racial stocks might be profitable if of a high average intelligence and wide variability.

What we want, then, in brief is such a selection of European peoples that they will add variety to our population but not lower its intelligence. We have, of course, the comparable problem of preventing the continuance of inferior lines in the present population in this country without adding any more congenital liabilities to our people.

In conclusion the writer wishes to submit a few comments upon the practical phases of immigration problems which he believes grow out of these partial but significant investigations of mentality in immigrant stocks.

(1.) There must be a change in public opinion as to the desirability of large numbers of immigrants. We acquired the habit previous to 1914 of pointing proudly each year to the rising influx of foreigners into our land. The economic exploitation of cheap, unintelligent labor from abroad has fastened a serious racial as well as social-economic problem upon us. It has resulted in considerable ethnic displacement. The "Older Immigration" has con-

[22] *Supra*, p. 2—ref. Retzius, etc.

[23] *Cf.* East and Jones, *Inbreeding and Outbreeding*, p. 264.

stantly lost ground in the face of the "New." The public opinion of this country needs arousing to opposition to the policy of economic stimulation of immigration to this country for the profits of the few at the expense of the general well-being.

(2.) This means that immigration should be controlled in the interests of the national welfare. The present law is inadequate, unjust and ill-administered. To base the percentages of admission on the number of immigrants of various nationalities in this country in 1910 is merely to continue relatively the same evils as heretofore. At present there seems to be some evidence that desirable people from Northern Europe and certain English colonies are being kept out while the ratio for Italians and Southern and Southeastern Europeans is large because of the "high" tides of immigration which they reached previously. Moreover, a literacy test is not an adequate criterion of the kind of persons we want. Due to inequality of educational opportunities in Europe, it is likely that persons of good intelligence may be barred because they can not read or write while persons really subnormal, but possessed of a modicum of education are able to pass the meagre demands on their reading and writing abilities at the gates of the country. Davenport has suggested a study of family strains in Europe, but this is expensive and impractical of execution.

The writer believes a set of well-worked out physical and psychological tests applied to all applicants for entrance into this country would assist in rejecting those whom we do not want. While the psychological tests are not perfect, they are far superior to any other scientific means which are available. The remarkable success of mental testing in our military organization during the war should dispel serious doubts as to the practical value of psychological tests for determining intelligence rankings and from that predicting success at tasks such as modern complex society demands. It would well repay our government to spend a considerable sum if necessary (say half the cost of one battleship) to devise under expert advice a set of tests to fit the needs of the immigration bureau. With adequate time at their disposal a body of experts could arrange a battery of tests, with norms, superior to anything yet at hand. Tests could be devised which would take into account the different linguistic and cultural backgrounds of the applicants, and further the non-verbal test offers possibility of expansion that is still unknown. On the basis of such tests, legal enactment could determine the standards to be set. In addition, if necessary, some differential standards on absolute numbers admissible any year could be laid down. It seems to me that there is not a better piece of service for the National Research Council than

an attack upon this problem with an effort to secure the national government's support and adoption.

True, there remains after such a program, if it is ever accepted, the entire matter, noted already, of the inferior strains in the population now present in our country. Were we to set out on a sensible program regarding the immigrant, we should be led ultimately into another analogous one concerning the inferior stocks already extant in our population. Linking up these two programs with a sane educational policy we might look forward to a true national greatness. For who doubts that the contributors to a high culture must be a high-minded race?

On the other hand, if we continue our present muddling, irrational, hit-and-miss method of dealing with these two related problems and the country becomes more and more inundated with inferior stocks, the questions of American citizenship, education and cultural progress will be increasingly difficult of solution. In fact, ultimately such problems as we now see them will be submerged in the low standards of life and culture which arise out of a lessened average intelligence in the general population.

The picture may be pessimistic. It should arouse us to action. To those who are pragmatists and meliorists the matter is not hopeless, except in so far as the individuals and communities involved fail to recognize the gravity of the matter and naïvely close their eyes to the realities. Blind leaders of the blind, we may well shake our heads in serious meditation. But if the public consciousness of the country, under good leadership, realizes the problem soon enough there is no reason why we should not successfully solve this issue and assure our country's place of leadership in the world.

CONCEPTUAL THINKING[1]

UNIVERSITY OF PITTSBURGH

By Dr. WALTER LIBBY

IN the recent newspaper controversy concerning evolution, one of Mr. Bryan's supporters displayed some impatience at the emphasis placed by scientists on resemblances. He protested in the name of logic against what seemed to him an undue insistence on resemblance, resemblance, resemblance! But unless we take account of the similarity among phenomena, how are we to arrange and classify the data of physics, chemistry, botany and zoology, or arrive at the concepts of which the propositions and syllogisms of the logician are composed? We can have no science of distinct existences ununited by the bond of likeness. It is only by virtue of resemblances that we are enabled to pass from the observation of particulars to the consideration of universals. Bain and other psychologists are so far from belittling the ability to discover the bond of similarity among phenomena, often apparently unlike, that they regard it as characteristic of the man of genius. For James, genius is the possession of similar association to an extreme degree. To the type of genius that *notices* the identity underlying cognate thoughts belong the men of science, and it is in the concept that the conscious identification takes place.

Conception, or the cognition of the universal aspects of phenomena, can be illustrated from the history of the biological sciences. For example, what Linnaeus called the "System of Nature" was in reality a system of concepts. His classification of plants, though it prepared the way for more natural classifications, was crude, because based on superficial similarities. He, as Harvey-Gibson says, "elaborated a complex and beautifully arranged and catalogued set of pigeon-holes and forced the facts that Nature presented to him into these pigeon-holes, whether they fitted the receptacles or not." His zoological concepts were likewise inadequate. Suffice it to recall his vague use of the terms *Insecta*, *Vermes* and *Chaos*. The likenesses revealed in animal structure by the comparative anatomists from Hunter to Cuvier and Owen led to a sharper definition of concepts and a more satisfactory classification. Paleontology afforded new materials for

[1] The second lecture in a series entitled "The Psychology and Logic of Research" given before the Industrial Fellows of the Mellon Institute, February 14 to May 2, 1922.

comparison. Lamarck introduced the term *Invertebrate*. Embryology and the use of the microscope led to fresh observations of likeness and to the establishment of the natural affinities of species and genera. Here might be mentioned particularly the discovery of the notochord—the key, as it has been called, of vertebrate anatomy—and the consequent use of the term *Chordata*. The coming of evolution made possible a phylogenetic classification of organisms and a subtler differentiation of biological concepts.

The dominance of conceptual thinking in the classificatory aspects of science is fairly obvious. For example, in adopting the terms *Quercus alba, Q. rubra* and *Q. salicifolia*, the seventeenth-century taxonomist merely associated a definite nomenclature with the distinct concepts of Virginian woodmen, who had observed the likeness of American and British oaks. In other aspects of science, where the importance of the concept is far less obvious, it is none the less real. In the study of human anatomy by means of dissection it is generalized or conceptual knowledge that one seeks and retains. Anomalous or exceptional structures—such as a triceps muscle in place of a biceps, or an over-developed *panniculus carnosus*—are either disregarded and forgotten, or remembered as anomalies and exceptions. In any case, what the student retains, after two years spent in the dissecting-room, is a generalized knowledge of the structure of the human body and not a memory of the particular cadavers that seemed to occupy the focus of his attention. The case is somewhat similar with your natural history museum. The biological collections consist wholly of dead symbols of living things. Bones are frequently represented by masses of limestone or silica. A single specimen may do duty for a species, genus or order. The mere external surface—the shape—may alone be preserved. Only one stage in an animal's development may be exhibited, or only one posture—the Megatherium pulling down a tree or a dinosaur in a more or less characteristic pose. Each specimen has value not as representing an individual but as symbolizing a group. Each concrete object, like a word in a catalogue, serves to recall a concept.

The importance of cultivating the habit of conceptual thinking has been definitely recognized since the time of Plato, and Plato's master, Socrates. The majority of people, according to the Platonic dialogues, are the slaves of their senses and never attain to a system of clear concepts. They fail to translate their perceptions into conceptions and to pass from the sensible world to the supersensible or intelligible world. Plato valued the sciences with which he was best acquainted—mathematics and astronomy—because they tend to wean the mind from what is sensory and transitory to what is conceptual and eternal. The concept triangle,

the triangle of definition, is more real than any of its visible representations. Discipline in conceptual thinking is perferable to utility. "You amuse me," he writes, "by your evident alarm lest the multitude should think that you insist upon useless studies. Yet, indeeed, it is no easy matter, but, on the contrary, a very difficult one, to believe that in the midst of these studies an organ of our minds is being purged from the blindness, and quickened from the deadness, occasioned by other pursuits—an organ whose preservation is of more importance than a thousand eyes; because only by it can truth be seen."

Plato's philosophy is interesting for us because modern science is just such a system of clear concepts as he had in mind, and it is a mistake to interpret his intelligible world as something invisible to-day but accessible to the senses at some future time. The scientist must turn away from the sensuous world of the artist and the child to the intelligible world of mathematics, physics and biology; from the eight or seven little boys seated on a fence to cube root and prime numbers; from the panorama of many-colored nature to the conceptual world of elements, atoms, ions and electrons. The sciences are a sort of shorthand way of conceiving phenomena. They do not give us nature in its richness and fullness. In the words of Mephistopheles, "Gray, dear friend, is all theory, and green the golden tree of life." Picturesqueness is sacrificed by the scientist for the sake of clearness and economy of thought. He casts his net now for one kind of fish, now for another. For an artist like Monet, water may be a shimmering variegated surface; for the child it may mean "to drink;" while for the chemist it may be H_2O, or, if he conceives it as an alcohol, H.OH.

Of course science has no monopoly of clear conceptions. In insisting on the value of an education in conceptual thinking, Plato had in mind the training of leaders in ethics and statesmanship, and thus anticipated by a few centuries the publicists and philosophers who to-day advocate, as a novelty, the application of the intellect in social and political reform or proclaim the cultivation of the scientific habit of mind as the sole means of maintaining and advancing contemporary civilization. He would have recognized Lincoln as a man of clear conceptions, gained through a unique self-education, by living in close contact with man and nature, by reading a few books with extraordinary care, by poring over the statutes of Indiana, studying grammar, arithmetic and surveying, conning the dictionary, passing in review the life of Washington and the history of the United States, following with a frontiersman's imagination the exploits of Robinson Crusoe, absorbing the wisdom of Aesop's Fables, weighing the moral principles of The Bible and The Pilgrim's Progress. Indeed,

clear conceptual thinking, the scientific habit of mind, was consciously cultivated by the moral philosophers of Greece, notably by Socrates, whose chief distinction is that he subjected to critical examination such concepts as virtue, temperance and justice. Speaking of this pioneer work, Stout says: "It is only at a late stage of mental development that an attempt is made to distinguish an identical or persistent element of meaning pervading the varying significations of a word. When the attempt is made, it constitutes an epoch in the history of thought. It is the beginning of definition and of the scientific concept."

Conception, or thinking the same in like circumstances, has its complement in discrimination. Association by similarity is offset by dissociation, integration by disintergration, synthesis by analysis, and the observation of congruity by the observation of incongruity. In this respect, there is a marked difference between one individual and another. Experiment shows that one student may recognize readily ten shades of gray where his classmate has the greatest difficulty in discerning any difference in shade whatever. Similarly, one mind is alive to shades of meaning that make no impression on another. Aristotle, the greatest of all scientific intellects, trained for twenty years in the school of Plato in conceptual thinking, the most acute among the Greeks, as he has been called, in noting differences and making distinctions, carried his investigations into almost all the realms of knowledge. His success was most marked in fields where his aptitude in the employment of general concepts was supported by a wealth of observational data. This is particularly remarkable in his researches in biology. In the *Historia Animalium*, for example, one discovers the trained thinker bringing order out of chaos by the application of the intellect to the facts of experience, so called. It is the custom among historians of a conservative type to belittle the medieval followers of Aristotle, and above all the scholastics. But even to scholasticism modern science is deeply indebted for the development of logic in general, and for the definition and differentiation of concepts in particular.

The use of language is the indispensable concomitant of clear conceptual thinking. We can not think of one of the lower animals advancing very far in logical thought. He is bound down for the most part to the fleeting images of things, and lacks the word (logos) by which they might be made permanent and independent of the continuum of experience. The intellectual development of the child proceeds as a rule *pari passu* with its command of appropriate terms. "Out of hundreds of English-speaking children," says Terman, "we have not found one testing significantly above age who had a significantly low vocabulary;

and, correspondingly, those who test much below age never have a high vocabulary. Occasionally, however, a subject tests somewhat higher or lower in vocabulary than the mental age would lead us to expect. This is often the case with dull children in cultured homes and with very intelligent children whose home environment has not stimulated language development. But even in these cases we are not seriously misled, for the dull child of fortunate home surroundings shows his dullness in the quality of his definitions, if not in their quantity; while the bright child of illiterate parents shows his intelligence in the aptness and accuracy of his definitions.'' Terman thus makes it clear that intelligence is not to be gauged by the extent of one's vocabulary, but by the exactness with which concepts are defined.

In the interests of the progress of both science and democracy, it is important that training in the precise use of words—especially the derivatives of those languages from which we draw our general concepts—should not lag behind other conditions of the development of the immature. As Walter Lippmann says, ''Education that shall make men masters of their vocabulary is one of the central interests of liberty.'' Franklin's success, both as a statesman and a scientist, was in no small measure owing to the severe drill in the use of the English language to which he subjected himself. Two other self-educated research men, namely, John Hunter and Michael Faraday, who, on first thoughts, might seem to bear witness against the view that language training is of importance in scientific investigation, prove on examination to furnish testimony in corroboration. John Hunter received little if any schooling. He turned in contempt from the opportunity of studying the classics at Oxford. Although, after reaching maturity, he was brought, through the closest association with his brother, William Hunter, in contact with scholarly traditions, he never overcame the defects of his early education. We are indebted to him for such concepts as ''arrested development'' and ''secondary sexual characters,'' but his pages are strewn with terms like ''the stimulus of death,'' ''the stimulus of imperfection,'' and ''sympathy,'' to which he assigned a significance now impossible to recover. The lack of language training, in spite of Hunter's genius and vivid personality, was detrimental to his influence as a lecturer and writer. Owing to this shortcoming, science has not yet reaped the full harvest of his tireless energy in research. For example, the recapitulation theory, as stated by him, seems to-day little more than a literary curiosity, though it may have influenced the progress of embryology through the interpretation of the younger Meckel. The case of Faraday was somewhat different from that of Hunter. Having received an elemen-

tary education, Faraday became apprenticed to a book-binder. For years he spent his leisure time in reading scientific works. At the age of twenty-one he gained the favor of Sir Humphry Davy by a lucid report of some lectures delivered by Davy at the Royal Institution. Faraday became Davy's assistant, traveled on the Continent with his patron, studied foreign languages, and made definite efforts to acquire the oratorical arts of Davy, a recognized master of scientific diction. Faraday's opportunities for language training, however, came just a little too late. He sometimes confessed his difficulty in formulating the ideas that occurred to him. He sought aid at the University of Cambridge and was indebted to Whewell for such terms as "electrolysis," "electrolyte," "ion," etc.

Language permits us to summarize nature, to express it schematically, to seize upon certain aspects of it—that is, to analyze phenomena with certain purposes in view. For Priestley the part of the atmosphere that supports life was "pure dephlogisticated air." Lavoisier substituted a new term and a new conception, viz., "oxygen." Davy spent a great deal of time proving that Lavoisier had a false conception of the element discovered by Priestley. We retain the name after having modified the concept. This we do with the greater freedom, seeing that the classical term "oxygen" is not self-explanatory, as is the analogous term "Sauerstoff." Gases were known in the last quarter of the eighteenth century as "kinds of air," or "factitious airs." As late as 1766, Cavendish called hydrogen "inflammable air." In 1783 and 1785, he made experiments that justify the conceptions expressed by the terms "hydrogen" and "nitrogen." It was almost impossible to think clearly concerning earth, air, fire, and water, the so-called elements, without having the terms "oxygen," "nitrogen," "hydrogen," etc., as symbols of the concepts corresponding.

Counting, measuring, weighing—the application of mathematics—must be regarded as among the best means of sharpening up our conceptual thinking. One classical example is Lavoisier's use of the balance in establishing the nature of combustion and giving phlogiston the quietus. "About a week ago," he wrote on November 1, 1772, "I discovered that sulphur in burning, so far from losing weight, rather gains it; that is to say, that from a pound of sulphur more than a pound of vitriolic acid may be obtained, allowance being made for the moisture of the air. It is the same in the case of phosphorus. The gain in weight comes from the prodigious quantity of air which is fixed during the combustion and combines with the vapors. This discovery, which I have confirmed by experiments that seem to be decisive, has made me believe that what is observed in the combustion of sulphur and

phosphorus may equally well take place in the case of all those bodies which gain weight on combustion or calcination. I am persuaded that the gain in weight of the metallic calces is owing to the same cause." Lavoisier followed up this work by the calcination of tin in 1774, and in the same year—after Priestley's discovery of "pure dephlogisticated air"—by the oxidation of mercury. In 1777, Lavoisier stated: that in all cases of combustion heat and light are evolved; that bodies burn only in oxygen (or *air éminement pur,* as he at that time called it); that oxygen is used up by the combustion, and the gain in weight of the substance burned is equal to the loss of weight sustained by the air.

The differentiation of terms and concepts is so necessary an accompaniment of the advance of science that no collection of examples can be regarded as adequate or as even fairly representative. Though Lavoisier in 1777 succeeded in giving to the concept "combustion" a much more clearly defined meaning than had attached to the "fire" of the ancient philosophers or the "flame" of Francis Bacon, in 1789 he still included "calorie" and "light" in his table of elements. In spite of the definition by Robert Boyle of the concept "element," and the attempt of Newton to determine the meaning of "atom," these ideas, inherited from the remote past, were at the close of the eighteenth century about to enter on a new series of transformations. In the seventeenth century Boyle's contemporary, John Ray, ascribed to the term "species" a definite, if not a final, significance, and Sydenham, seeking to establish by clinical observation distinct species of disease, succeeded in differentiating measles from smallpox, in defining chorea, in modifying the significance of the term "hysteria," etc. Progress in science may involve lessening or increasing the extension of a familiar term, determining anew the distinction between familiar terms, and introducing new clearly defined terms. Pasteur's studies in molecular asymmetry involved a reconsideration of the terms "tartrate" and "racemate" and a delimitation of the concepts which each of these terms expressed. An advantage is gained by substituting the unfamiliar "neurasthenia" for the familiar "nervousness," partly because the new term is unambiguous and partly because it is devoid of every popular connotation. In fact, our scientific terminology has become so much a thing apart that one may overlook the relationship between a common term like "weight" and a more technical term like "mass."

The researches of Schleiden and Schwann, which led up to the statement of the cell theory, were affected and, to some extent, vitiated by traditional conceptions concerning "cellular tissue" and the "cell." Robert Hooke was the first to use the term "cell"

in describing organic structure. He had examined charcoal, cork, and other vegetable tissues under the microscope and described them in 1665 as "all perforated and porous, much like a honeycomb." He could discover no passages between the minute cavities or cells, though he took it for granted that the nutritive juices to be seen in the cells of green vegetables had some means of egress. Hooke's observations were verified by his contemporaries. Grew, in describing the microscopic structure of plants, mentioned the infinite mass of "little cells or bladders" of which certain parts are composed, and Malpighi described the cuticle of the plant stem as consisting of "utricles" arranged horizontally. Caspar Wolff in his doctor's thesis (*Theoria Generationis*, 1759) reported the observation of cells and "little bubbles" which developed in the homogeneous layers of the embryo. In the works of Bichat, the founder of histology, the term "cellular tissue" was used, as indeed it is to-day, to indicate a certain kind of connective tissue. Treviranus and Link described the cells in vegetable tissues in 1804, the latter maintaining that they are closed vesicles incapable of communicating with each other. Professor John H. Gerould has recently pointed out, in the pages of *The Scientific Monthly*, the important part taken by Lamarck, Mirbel (the disciple of Caspar Wolff), and others in the development of the conception of the "cell" and of "cellular tissue." After the appearance of Moldenhawer's *Contributions to the Anatomy of Plants* (1812), which demonstrated that the cavities of vegetable cells are separated from each other by two walls, the attention of observers was diverted from the cell contents to the cell wall. The consequent misconception of the nature of the cell was in part corrected by Robert Brown's discovery of the cell nucleus and by the later discovery of protoplasm. It was before the full significance of the cell contents was realized that the cell theory was conceived by Schleiden and Schwann.

It is evident that advances in scientific thinking imply the use of clear concepts and clear terms. The term "neuron," employed by the early Greeks in the sense of "thong" or "sinew," was applied by the anatomists of the fourth century B. C. to the tendon as well as to the nerve. A considerable treatise alone would suffice to trace its subsequent meanings and those of its derivatives and at the same time to give an account of the investigations that from the time of Herophilus and Erasistratus have contributed to the elucidation of the concepts in question. The terms that represent to-day the so-called chemical elements have no doubt undergone a similar series of transformations in meaning. Distillation, crystallization, and other refining processes had to be brought into play before the concept—the spirit, the essence, the thing in itself—could be realized.

"WHO'S WHO" AMONG AMERICAN WOMEN

By Professor STEPHEN S. VISHER and
GERTRUDE HOVERSTOCK
INDIANA UNIVERSITY, BLOOMINGTON

CATTELL has made some stimulating statistical studies of the more eminent scientific men, including the distribution of their birthplaces and of their present residence.[1] Some years ago a study of the distribution of the first ten thousand persons in "Who's Who in America" appeared in this journal.[2] The conclusions drawn from these studies, while not to be seriously doubted, are so interesting that it appears worth while to test them by a similar study of a different group of notable people—the 1,687 women included in the last edition of "Who's Who in America" (Vol. XI, 1920-21), especially the 1,582 women concerning whom biographical data are given.

The distribution of the place of birth of 1,551 women who gave this information is indicated by districts in Table 1, as is also the ratio between eminent women and the general population of 1880.

TABLE 1

BIRTHPLACES OF WOMEN IN "WHO'S WHO IN AMERICA"

District	Number	Per cent.	Number per 100,000 at 1880 census
New England	333	21.5	8.3
Middle Atlantic	511	33.0	4.3
East North Central	347	22.4	3.1
West North Central	99	6.2	0.5
Southern	101	6.5	1.6
Mountain and Pacific	49	3.2	2.8
Foreign countries	112	7.2	....

This table reveals the prominent share New England has had in the production of eminent women, and the small share which the southern and western halves of the nation have had. "Who's

[1] J. McKeen Cattell: "Families of American Men of Science." *The Popular Science Monthly*, May, 1915, and THE SCIENTIFIC MONTHLY, October, 1917 (reprinted in "American Men of Science," third edition, 1921). An earlier study based on the starred scientists in the first edition is reprinted in the second edition of "American Men of Science," 1910.

[2] Scott Nearing: "The Geographical Distribution of American Genius," *The Popular Science Monthly*, Vol. 85, pp. 189-199, 1914.

Who in America'' is published in Chicago and is edited by an Ohioan.

Of scarcely less interest than the variation among the districts is the variation among the individual states in the number of famous women they have produced. Table two shows for each of the leading six states the number and proportion of eminent women.

TABLE 2

SIX LEADING STATES IN THE PRODUCTION OF EMINENT WOMEN

State	Native	Per cent. of total eminent women	Ratio per 100,000 of general population in 1880	Number now residing in the state
New York	291	19.0	5.8	550
Massachusetts	171	11.2	9.5	237
Ohio	117	7.6	3.7	46
Pennsylvania	113	7.4	2.7	90
Illinois	90	5.8	3.0	107
Indiana	43	2.8	2.1	20
Minnesota	43	2.8	6.6	24

Table three gives the number of eminent women born in each state and the number now living there.

TABLE 3

BIRTHPLACE AND RESIDENCE OF EMINENT WOMEN BY STATES

State	Native	Resident
Alabama	19	10
Arizona	0	1
Arkansas	5	2
California	28	78
Colorado	0	14
Connecticut	54	62
Delaware	5	1
Florida	3	6
Georgia	9	13
Idaho	1	1
Illinois	90	107
Indiana	43	20
Iowa	24	11
Kansas	15	9
Kentucky	32	22
Louisiana	14	2
Maine	43	21
Maryland	28	80
Massachusetts	171	237
Michigan	33	17
Minnesota	18	24
Mississippi	10	2
Missouri	36	25
Montana	3	2
Nebraska	5	3

Nevada	2	2
New Hampshire	27	14
New Jersey	33	58
New Mexico	1	2
New York	291	550
North Carolina	7	11
North Dakota	2	2
Ohio	117	46
Oklahoma	1	1
Oregon	4	7
Pennsylvania	113	90
Rhode Island	16	11
South Carolina	4	3
South Dakota	1	0
Tennessee	20	10
Texas	6	5
Utah	3	3
Vermont	22	3
Virginia	35	16
Washington	7	12
West Virginia	6	5
Wisconsin	32	15
Wyoming	0	3
Countries outside U. S.	112	48
Not given	136	...
Total	1,687	1,687

This table indicates that Colorado, Wyoming and Arizona, having a population of 260,000 in 1880, produced no women who have been included in this issue of "Who's Who in America." Furthermore, Idaho, South Dakota, New Mexico and Oklahoma, having a total population of 451,000 in 1880, have each produced only one. Thus these seven states with a population in 1880 of 712,000 are represented in "Who's Who" by only four women. On the other hand, New England, which had a scarcely larger population in 1880, contributed 333 eminent women. Similarly, the Southern States, with an 1880 population somewhat greater than that of New England and the Middle Atlantic States combined, produced only 99 famous women in contrast with 844 from these northern states. Not only were few eminent women born in the South about 1880, but still fewer now reside there, 63 vs. 99. The North Atlantic and New England States have attracted many notable women with the result that 1,148 of the 1,687 women listed now live there. In other words, these states produced 54.5 per cent. of the eminent women, but now have 68 per cent. of the nation's total.

This great centralization of production of famous women and of their present distribution may be due to the following in-

fluences: The presence of more educational institutions in the northeast, and the greater emphasis placed on education there.

Unquestionably there are sectional differences in ideals. In parts of the South, for example, an intellectually ambitious woman is not in favor.

The fact that men outnumber women in the West tends to encourage early marriage in the West. Relatively sparse population and more recent occupation also tend to cause life to be on a somewhat more primitive plane, with less opportunity or incentive for the type of achievement recognized by inclusion in "Who's Who." Western women who do not marry early are more likely than eastern women to have opportunity to become school teachers, clerks or business women.

Selective emigation certainly helps explain the distribution of the birthplaces of the eminent. As a rule, the highly intellectual type do not become frontiersmen. Pioneering calls for physical vigor and daring rather than high education or unusual intelligence. Furthermore, the highly intelligent type generally are in fair circumstances, and it usually is the poor who emigrate, not the well-to-do. Hence, for a number of reasons, there is a tendency for the intellectual type of people not to emigrate, unless it be as missionaries, but to remain where they can make the most use of their ability and education. Thus many have remained in the older states, or have moved into the older communities in the Middle West, rather than going to the Newer West. Consequently, few infants possessing unusual intellectual endowment are born on the frontier or in the Newer West.

The presence of nearly ten million negroes in the South reduces the South's contribution of eminent women in proportion to its total population, for no negress is included in this volume of "Who's Who."

The climate of the North is more favorable for mental activity than is the often rather enervating climate of the South. It likewise favors physical vigor and thus increases accomplishment. Climate also doubtless has played a part in reducing the production of eminent women in parts of the West. While the climate of the arid and semi-arid west may possibly favor intellectual activity and physical vigor, it can not be disputed that the frequent droughts, unseasonable frosts, etc., have tended powerfully to encourage the emigrating of the exceptionally alert and resourceful people. Such people tend to go into regions where the opportunities are less uncertain.

In addition to place of birth and residence, note was taken of occupation, education and state of marriage. It was found that

53 per cent. of the last 950 women in "Who's Who" are married. Many occupations are followed. Eighteen chief types were listed. The most important eight, with the number engaged in each, and the per cent. of the total are shown in Table 4.

TABLE 4

OCCUPATIONS OF WOMEN IN "WHO'S WHO IN AMERICA"

Occupations	Number of women	Per cent. of women
Writers	714	45.3
Education	244	15.6
Social workers	127	8.0
Artists	117	7.5
Actresses	63	3.9
Singers	46	2.9
Editors	34	2.1
Physicians	28	1.7

In addition to these eight, there are lawyers, politicians, religious workers, librarians, scientists, lecturers, explorers, musicians, business women and those interested in home economics. Thus there is a very wide range of activities.

From Table 4 and other data a few conclusions appear warranted. One is that women receive recognition for writing more readily than in most activities. Nearly one half of the 1,582 women whose biographies are given are writers. On the other hand, comparatively few teachers have attained the fame of the type indicated by inclusion in "Who's Who," most of the "educators" included being administrators such as deans and presidents. Indeed, a considerable number of women are holding administrative positions.

The higher education of women was also noted, and it was found that 88 per cent. report training above the secondary school. Of the two groups attending college or college and university, exactly one half of the women report training in women's colleges.

TABLE 5

Type of training	Number of women	Per cent. of women
College	440	27.9
University	216	13.7
Special	466	29.5
College and university	205	13.0
College and special	39	2.4
University and special	23	1.5
None mentioned	190	12.0

This table indicates that few women who do not take advantage of existing opportunities for higher education (beyond the secondary or high school) now attain national fame.

GO TO THE BEE

A Contribution to the Permanence of Aristocracy

By Dr. DAVID STARR JORDAN
STANFORD UNIVERSITY

"THE Leisure Classes, the Chief Support of the Nation they adorn"—such was the topic of a remarkable sermon delivered not long ago to an audience of superior people, by the Reverend Vicar of Girlington, England, whose actual name I do not give lest my feeble words fail to interpret his lofty ideals. From the press notices that came under my eye, it appears that the admired and admirable vicar finds his mission in the salvation of British aristocracy through its complete restoration to the ranks of leisure. In his judgment the aristocrats or superior persons serve society best by standing as examples of human perfectibility. This is the end they should seek, through utter surcease from all worry, all effort and all personal hopes and desires.

The vicar would indeed make of the upper classes a group, not of hereditary rulers, but of elect examplars of what humanity may become, a condition to be open to a chosen few to whom is granted release from the sordid side of life. From such relief the great body of the British people are of course excluded—not from any fault or deficiency of their own, but simply because there is not leisure enough to go around. Thus for the chosen the mass must live; the many gather honey for the few to enjoy. But in fairness—and this I take it is the vital part of the vicar's contention—all should have an equal chance in the beginning.

A rationally organized society would then consist of two classes which for convenience the vicar might call the laborers and the leisurers. To the former belongs the capitalist as well as the workman; all indeed who work with hand or tongue or pen or brain labor alike. The leisurer alone enjoys that perfect serenity which comes from fearing nothing, wanting nothing, hoping for nothing. True happiness rests on a division of duty. A natural cleavage lies between those who create and those who enjoy, each condition having its own peculiar delight. Between the two yawns a great gulf which society crosses only at its peril.

The vicar's discourse harks back to the words of Solomon, "Go to the ant; consider her ways and be wise," an injunction inciting alike to modesty and to thrift, two virtues of which the ant is a

model. She knows her place and keeps it. Aspiration goes with aviation; having no wings, she never tries to fly.

But in addressing the leisurer the vicar would modify his text: "Go rather to the bee; consider his ways and be wise." Physically the bee resembles the ant, but his social system is organized on a more exalted basis. With him, the leisure class is unquestionably the chief support of the society it adorns. And now to make clear the vicar's appeal, I find it necessary to amplify the too meager report given in the *Girlington Guardian*, and without holding the speaker closely responsible, I may draw for the moment from the fascinating observations of the noted apiarist of Brussels, Maurice Maeterlinck.

Two salient facts at once appear: first, bee society maintains its own aristocracy; second, its leisurers, having no hereditary claim for distinction, are chosen by lot and by no effort of their own. As the young bees are about to hatch, their faithful nurses construct a few cells of extra size and feed the occupants on a special food, the "royal jelly" of the apiarist. These selected individuals, the "queens," then grow up in an atmosphere of leisure. To produce the harmonious and perfect bee for which the toiling workers exist is the culmination of the apiarian system.

In carrying the analogy into human society, the essential point (as I think the vicar would agree) is that among men as among bees, no injustice shall be done. Leisurer and laborer must both exist, but as both are of one lineage, each should have an equal chance for the great prize of existence. That "the rank is but the guinea's stamp, the man's the gold" is literally true. Royal jelly and a royal cell make the bee-aristocrat. The difference between queen and worker is purely one of bringing up; the two are of the same blood, the queen becomes regal without effort of her own.

By like means human society may breed its aristocrats—so reads the lesson to be learned from the bee. The queen exists not for her own sake, nor by inherited right. Neither should a lord among men, his only true function being to round out the humanity of his fellows, show what man has it in him to be if brought up without work or worry, marred by no trace of struggle, no fear of defeat, by nothing which wrinkles the brow, makes callous the hands, nor hardens the heart! Lacking this perfect ideal, end and aim, humanity can never realize itself.

Perfection, by the very nature of things, is denied the laborer. Yet how vital it is that perfection should exist! Plainly, however, only a few can be leisurers, though in life's grand lottery all may start alike. The needs of the hour call for the "man with the hoe," the woman at the washtub. Some must toil and spin that the human lily may be properly arrayed. Mark, too, the perfect rose,

"its own excuse for being," yet dependent on stem and leaves and roots for very existence. Moreover, its glowing petals are but leaves transformed and perfected. Thus from the lily or the rose one may draw the same lesson as from the bee and the ant.

In his implied criticism of the British aristocracy of the renowned Victorian era, the vicar proceeds with becoming modesty. It would seem indeed presumptuous in the holder of a living, the gift of a gentleman of the county, to say one word in dispraise of conditions as they are. The very essence of organized religion is conservatism.

Yet some one must turn his face towards the light, and every student of history knows that the "Decline of Aristocracy," as defined by one of its illustrious examples, Mr. Arthur Ponsonby, is now imminent. The only way of avoiding decadence is to place aristocracy on a democratic basis, as it were, to open its doors to all, but at the same time keep the passage narrow so that few can enter. "Strait is the gate, and narrow is the way" that leadeth to perfection.

The Victorian system is open to cavil on three sides: it is hereditary: it is open to invasion by wealth, it is used as a reward for achievement.

As for heredity, one easily sees that mere aristrocratic descent does not guarantee a perfect leisurer. "Blue blood" tends to run thin, and in-and-in breeding plays havoc with the human stock as well as with dogs and horses. Furthermore, inheritance smacks of privilege, and the iconoclastic Georgian Age will have none of it. No youth is now willing to follow his father's trade. The son of a tailor no longer sits cross-legged on a bench if fate has taken him early in hand, the son of a non-conformist preacher becomes prime minister—and one never knows *where* it is all going to stop! But any healthy boy, caught young enough, is soon aligned with the customs and opinions of his entourage. Set among gentlemen, nothing is easier than to act like a gentleman! As a matter of fact every wise butler soon acquires a manner as lordly as that of his master, whom he often instructs in the higher etiquette. Frequently he has had longer experience, and has given to items of behavior more serious thought. A sympathetic moisture of the eye and a gentle lowering of the voice in delicate moments may come as natural to him as to a bishop. Stephen Leacock of Montreal, a noted American tourist, gives an amusing account of his call upon an ambassador of the United Kingdom. At the end of a discussion concerning the weather and the future of the Empire, he was still doubtful as to whether he had met the ambassador or his butler. To test the matter, therefore, he slipped a gold sovereign into the hand of his host. The coin was accepted, but in such a detached and dignified

manner that the visitor's uncertainty was not dispelled by his maneuver.

With a "young person," the process of adaptation is even more rapid and sure. The charwoman's daughter brought up as a lady yields to none in ladylike perfection. Napoleon even went so far as to propose that women should have no hereditary rank at all, but content themselves with the title of their consorts. Presumably his experience with the stalwart insistence of his otherwise plebeian sisters whom he had personally ennobled determined his attitude in that regard. But most of us are familiar with the career of the Honorable Lady Burnett, a woman of humble origin as her friends admit—once a milkmaid or (according to traducers) a barmaid, who became through an exalted marriage "the arbitress of the elegances for all the region about her husband's manor house." From the *Morning Post* one learns that "she used, queen-like, to reign; nay, pour at tea in the newest and tightest of white gloves," and with that undefinable *je ne sais quoi* which marks the true aristocrat!

An aristocracy has been defined as "a social superstructure reared on a foundation of bestness." There is but one permanent basis for "bestness." This is implied in the thousand year old motto of the aristocratic Winchester College, "Manners makyth man," or in the modern vernacular, "Handsome is as handsome does."

The vicar, himself of humble birth but aristocratic connections, admits freely that it is too late in the day to lay stress on lineage. We all claim Adam as a forbear, and not one of us has ever had even a single ancestor weak enough to die in infancy. Leisurer or laborer, each has weathered the storm; in that sense, all are noble alike. Genealogists also affirm that we unmixed English people are all of Plantagenet stock, most of us through the first three Edwards, descended from William, Alfred and Charlemagne. Indeed, one eminent authority classes all Englishmen together as the "inbred descendants of Charlemagne," and Charlemagne (as we know) was at the head of a League of Nations, being at once King of France, Emperor of Germany, and Overlord of Europe. Noble blood indeed is ours, but unfortunately so many share it that it can not serve as a test of aristocracy.

Again, large numbers of our so-called nobility have arisen through long years of struggle directed toward that end. Social extrication is a form of hard work, and labor of whatever kind mars the soul as it wrinkles the brow. A furrowed face is of itself a badge of serfdom. A mind too alert, an ambition too urgent, tends to defeat the purpose of social adornment. To diffuse sweetness and light is not an arduous occupation. Indeed to give

thought to it or to make it a result of definite effort is to fail in the most important element. The leisurer who goes down into the East End to mend the manners of the poor would do better to confine himself to awarding the conventional goose and bottle of ale at the happy season of Christmas. Those who have pursued this policy enjoy a devout gratitude heightened by its rarity. If life for the laborer was all ale and goose —or beer and skittles, as vulgarly paraphrased—no one would know his place, and the barriers betwixt laborer and leisurer so carefully built up in the long centuries of England's glory would be completely broken down.

Browning paints the ideal leisurer as a king who "lived long ago in the morning of the world" with a forehead "calm as a babe new born." This is an enchanting ideal, but the further description (so familiar that I need not quote it here) does not fit their lordships of to-day. No one would take it for a portrait of Northcliffe, Carson, or Birkenhead, whose bustling activities keep the realm in turmoil. An aristocracy founded on labor of mind or hand is not a class of leisurers. Like my Lord Bottlebrush and the "Duchess of Draggletail" in Thackeray's satire, however high the circle in which they move, their manifest lack of noble repose only swells the confusion.

Moreover, no genuine aristocracy can be founded solely on wealth. The "bounder-nobility"—as an irreverent press styles them—are noble in their own eyes alone. In an exalted circle money should never be thought of, much less mentioned! The bee queen builds no cells and gathers no honey. No increment of beebread or royal jelly is due to her own activities, or received by inheritance. Queen and environment are alike parts of one system. So it should be with a true aristocracy. No quest of gold, no promotion of enterprise, no regret over the past, no worry for the future, no will to know, no call to govern, no mission to control, no fear of loss, no hope of gain, ought to intrude to break the perfect peace. Kept in place by a reverent society, the Lord of Leisure need only pose as the glint of a sunbeam across the trail of the toilers, merely strew flowers along the pathway of life, in short be like

> Roses in their bloom
> Casting their petals ever on the grass
> Over the way the Beautiful must pass.

II

To all this there is an intensely practical side. If aristocracy is to endure (and without it this would be a dreary world indeed) it must be constituted aright. It must reject the false bases of heredity, effort and wealth. It must not be the reward of dis-

tinction, nor be attainable by any competitive examination. Its door should open to all on equal terms, even though straight the gate and narrow the way. The present House of Lords, now swollen to seven hundred members, including almost everybody able and willing to pay the price, will die of its own accord. Let it alone. Let the climbers of yesterday keep on climbing, while we remove the ladders behind them. Let the men who replenish the party treasuries receive in the name of our gracious King—our sole true aristocrat—whatsoever honors their patriotism deserves; but for the good of society let us build a new class in a new way. Should we fail in that endeavor the iconoclasts of the day will cast us all into the melting-pot from which no leisurer returns, an upshot the vicar would sadly deprecate.

To select noblemen by primogeniture is a process comparable to choice by loaded dice; the cast is made before the heir is born. Nothing could be more undemocratic, nothing in reality more unfair to men and women of the race in general. Then let our lords be chosen by lot from among the people at large, let us pick a certain number of babies to be our future leisurers, and feed them on royal jelly[1] or the nearest parallel to that condiment our gracious King may secure.

All expense involved should of course be carried by the people. In the United Kingdom are some 48,000,000 men and women. Let each pay alike; the assessment would then be so small that no one would even notice it. Let each contribute say a penny yearly for social inflorescence—for the perfected blossom of humanity. Such trifling levy would amount in the aggregate to £200,000 sterling, which, judiciously invested, would yield an assured annual income of £10,000, a sum quite adequate to provide for a leisurer throughout life. And the contribution by everybody of one shilling, a tax still absurdly small, would support twelve members of the new aristocracy each year.

The necessary sum once collected, the infant chosen should be entirely healthy, and so attested by a Court physician accustomed to the needs of the leisure classes. It ought also to be a manchild, and its future mate, having no title in her own right, would become a "Lady" by courtesy, even as now the wife of the knighted grocer or jockey is recognized as "Lady" Jones or Atkins because her husband has been touched by the flat of the King's sword and allowed to write "Sir" before his name. Only through an impartial selection may aristocracy and democracy be satis-

[1] This expression is of course purely figurative, because no product of Cross and Blackwell serves our indicated purpose. It is with the general problem of perfected environment that we have to deal.

factorily reconciled; and only when begun before effort, ambition or deterioration has set in can the budding leisurer be adequately trained by nurse and butler in the thoughts and manners proper to a perfect lord. Otherwise, less lovely traits might have become stiffened beyond remedy.

As his lordship grows up, the necessary allowance should come to him in regular sums only. He should never forestall, never hoard, never gamble, never speculate, never go into trade, never run into debt, never have anything left over after Christmas! He should support society as society has supported him; but chiefly he and the lady he may happily choose must remain through life "on the hills as gods together, careless of mankind."

True, as the noble Lord Tennyson once observed, "kind hearts are more than coronets," but there is nothing in the plan to inhibit possession of both at once. A coronet, moreover, may be very becoming as well as very welcome to My Lady. For our new-made lord will never marry for money nor as a rule where money is—all dowry acquired being turned over to the state; and what more exquisite pleasure than that of a young maiden unexpectedly chosen for the high distinction of a coronet! Let us also notice the amazing widening of the possible range of choice when no dowry need be sought.

Doubtless a new title ought to be devised for the consummate flower of leisure. Lord, Duke, Earl, Knight—all these hark back to the discarded emblems of war, "the faded fancies of an elder world." The vicar himself, I believe, was undecided, but the plan developed from hints given in his discourse should not fail just because a suitable name is not immediately forthcoming. The hellenistic term, "Bianthine," "flower of life," would be appropriate, but it seems rather long, used as we are to the abrupt Saxon "Lord and Lady," or the Norman "Sir." "Flovite" *(flos-vitæ)* might do; represented by the letters F. V. it would be a natural contrast to M. P., and a pleasing reminiscence of F. F. V., the designation of certain *Élite* of the United States of America. This again suggests that the word *Élite* itself, a good Norman expression much valued by our Gallic allies, may be the term we are seeking.

In any case, the title selected should in some way indicate one chosen from among many, first among equals, the bloom of existence, the triumph of aspiring democracy reaching the goal of perfection amidst the leaven and the levelling of the commonry. And we hope that the admirable vicar may find ample support in his noble crusade to make the British peerage once more a counsel of perfection.

THE FOOD RESOURCES OF THE SEA

By GEORGE W. MARTIN

ASSISTANT PROFESSOR OF BOTANY, RUTGERS COLLEGE, NEW BRUNSWICK, N. J.

PRIMITIVE man got his food as his competitors did—that is to say, he picked it up or killed it where he could find it. Very early in his civilized career he ceased to be a hunter and began to cultivate the land; in fact, the beginnings of civilization and of agriculture were contemporaneous. Since that time the pressure of increasing populations demanding to be fed has been a prolific source of human strife. There are not lacking economists who would maintain that the recent catastrophic war in Europe was the direct result of an increasing demand for food on the part of the rapidly multiplying German nation. East, in THE SCIENTIFIC MONTHLY for December, 1921, points out that the agricultural resources of the United States can in all probability not support in reasonable comfort more than two hundred million people and that the present indications are that our population will reach that figure within the next century. Furthermore, we can not count on importing food indefinitely, since by the time our own population reaches its limit, the now scantily peopled parts of the world will produce little or no food in excess of the needs of their own greatly augmented populations. His is but one of many voices warning us that there is a limit to the number of human beings whom the earth can support, and however we may disagree with the various estimates as to what the limit may be, we can not doubt that it exists, and that, historically speaking, we are rapidly approaching it. The purpose of this article is, however, not to consider this question in detail, but merely to point out one source of food of which the possibilities are still largely unrealized.

If we were to-day still depending upon the chase as the main source of our food, most of us would be dead, or, rather, we should never have been born. Yet so far as the oceans, which cover three fourths of the surface of the earth, are concerned, we have made little essential advance over the methods of the primitive fishermen. The flocks and herds of the sea still roam freely in their native haunts, and we cast our lines and nets over their feeding grounds, and catch what we can. Our operations are on a larger

scale, it is true, than those of our predecessors, our tackle is superior, our nets larger and stronger, and, by equipping our fishing vessels with steam or gasoline power, we have enlarged the area we can cover. Once the fish are landed, we have an elaborate system of distribution and marketing, so that cities a thousand miles inland can have fish a day out of the ocean shipped to them in fast refrigerated cars. There is also a little direct utilization of the plants of the sea. In certain parts of the world, notably in China and Japan, and to a less extent in Europe, a few of the algæ are eaten by man or his domestic animals, or gathered to be utilized in some minor industry. But so far as the actual cultivation of the sea's resources as distinguished from their mere exploitation is concerned, we have made only the feeblest beginning. The reasons for this are, of course, the uncontrollability of the sea as compared with the land; its instability; the vastness of the oceans and the relative inaccessibility of much of their area; and especially the difficulty of attempting to control living organisms in the sea, out of man's natural element, as they may be controlled on the land where he is at home. Yet if the demand becomes insistent enough we can not doubt that methods will be devised which will give us the desired results. To question that would be to admit that man has neared the culmination of his evolutionary career and is preparing to bequeath the mastery of the earth to his successor, whoever that may be.

The bulk of the food supply which we have come to expect the ocean to furnish us is animal. Animals that live in the sea are, however, no less dependent upon plant life for their food than are land animals. We all know that the beef we eat is built up from the grass and grain upon which the cattle have fed; and, while there are many animals that feed upon other animals only, sooner or later the cycle goes back to the green plants. This is because the green coloring matter contained in plants is the only substance known that can so combine carbon and water as to form the carbohydrates that are the fundamental materials of which all living beings, whether plants or animals, are constructed. The plants living in the sea are then the equivalents, so far as the life of the sea is concerned, of the land plants. Like land plants, they not only need carbon and water, but certain mineral salts. Of these, those that furnish them with nitrogen and phosphorus are most important, since they are most apt to be present in insufficient quantity and thus to be limiting factors. The plants in the sea are continually using these substances and are continually dying or being eaten by animals. Sooner or later there comes a time when by the death and decay of the plant or animal most of

these materials are returned to solution. Part, however, have been transformed into insoluble compounds and are lying inert in the depths of the ocean. Thus there is a constant loss of nutrient salts. This loss is replaced by drainage from the land, the great rivers carrying constantly into the ocean an almost incredible amount of dissolved minerals in addition to suspended matter.

Another important requirement of plants is light. Plants on land receive the full benefit of the sun's rays as we know them. Plants living under water receive only a portion of the rays that reach the land. Part of the light that strikes the water is reflected, and the part that penetrates the water is gradually absorbed in passing through that medium, the red and yellow rays first, the blue and violet last. This differential absorption is reflected in the curious and well-known vertical distribution of marine algæ according to color—the green kinds growing in shallow water, the browns in an intermediate zone and the reds in the deepest water, although there are, of course, numerous exceptions to this general rule of distribution. Another property of light is that it is refracted by water, and the greater the angle at which the rays strike the water the greater will be the refraction. In the tropics, where the rays are practically vertical, the amount of refraction is insignificant, but in high latitudes, where the rays strike the water at a sharp angle, the refraction is marked, as a result of which the rays are bent into a more nearly vertical direction, thus increasing their penetration in depth and partly compensating for the unfavorable angle at which they strike the water. The penetration is also markedly affected by the amount of suspended matter and the number of microorganisms present in the water. Helland-Hansen was able to show that in the Atlantic Ocean south of the Azores, on a bright summer's day, light is abundant at a depth of 100 meters, still including at that depth a few red rays. At 500 meters the red rays have completely disappeared, but blue and ultra-violet rays are still plentiful, and may be detected at 1,000 meters, but have completely disappeared at 1,700 meters. It is not probable, however, that under the most favorable conditions photosynthesis may be carried on at depths greater than 200 meters.

Temperature is less directly important in the sea than on land since there is no great danger of injurious extremes being reached. Indirectly, its importance lies in the fact that carbondioxide is much more soluble in cold water than in warm, (Fig. 1) and it is probably this, rather than the direct influence of temperature which accounts for the fact that the most luxuriant development of plant life is in the colder waters of the earth.

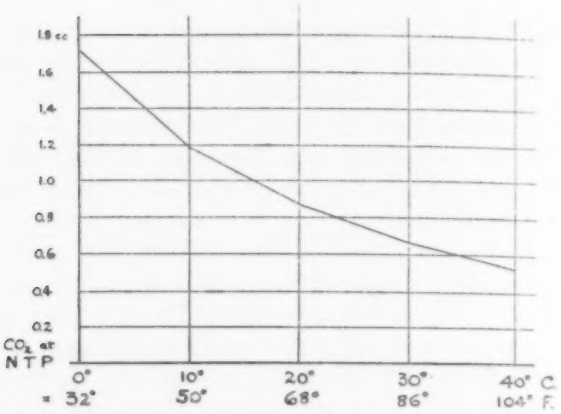


FIG. 1. SOLUBILITY OF CARBON DIOXIDE IN WATER. CUBIC CENTIMETERS OF CO_2 SOLUBLE IN 1 C. C. OF WATER, REDUCED TO NORMAL TEMPERATURE AND PRESSURE

On the basis of habitat, marine plants may be divided into two great groups. On all coasts, and in shallow waters near the coasts, there is usually a conspicuous zone of "seaweed." This is known as the benthos, from a Greek word denoting bottom, because it occurs attached to the bottom on the shelf of shallow water surrounding the coasts. The plants of the benthos are extremely varied and range in size from microscopic to very large, the giant kelps of the northern Pacific sometimes reaching a length of nearly four hundred feet. We are accustomed to think of these plants as algæ, and most of them belong to one or another of the great algal groups, but the most important of all the plants of the benthos is not an alga but a flowering plant, belonging to the pondweed family, and not very distantly related to the grass family, which is the most important economic family of land plants. This is *Zostera marina*, the common eel-grass. *Zostera marina* or some of its near relatives occurs on almost all the ocean shores of the globe, being absent only in the extremely hot and extremely cold portions. It grows in water varying from a little over a meter in depth at low tide, to depths of fifteen or twenty meters in certain clear Mediterranean waters; and in waters varying in salinity from that of the sea water of the open ocean to that of brackish bays and estuaries of less than half full salinity. It prefers mud, but will grow nearly as well in sand. It will not grow, however, where the bottom is composed of loose stones nor where the wave action is severe, and these localities are inhabited by the true algæ. The windrows of dead "seaweed" commonly found cast up on our Atlantic shores are very largely composed of *Zostera*. A few other flowering plants occur in salt or brackish water, but they are relatively unimportant.

The algæ of the benthos occur, as previously stated, in three rather indefinitely limited zones. In the quiet waters of shallow bays we find a great many green and blue-green algæ. Such forms as *Ulva lactuca* and *Enteromorpha intestinalis*, both often called sea lettuce, are typically found in such situations. The branching, feathery masses of *Cladophora* and the thick green felt of *Vaucheria* are also often prominent. The blue-green algæ are entirely microscopic, but often occur in great abundance. A species of *Lyngbya* frequently forms felted mats two or three inches thick and many feet across. Masses of *Spirulina* as large as a dinner plate are common. The plants which grow between tide levels or just below low tide, at places where there is considerable wave action, belong mostly to the brown algæ. Various rockweeds, belonging to such genera as *Fucus* and *Ascophyllum*, are common in northern waters, and the gulfweed, *Sargassum*, is typical of the forms growing in the warmer waters. Below low tide level the great kelps—the Laminarias and their allies—are the largest plants of the ocean, the larger species occurring, however, only in the cooler waters. The algæ of the deeper waters are mainly the reds, and the farther south we go the greater becomes the preponderance of the red algæ. It must be remembered, however, that red, brown, green and blue-green algæ are more or less intermingled at all depths and in all latitudes. All the plants we have been considering are alike, however, in that they occur only near the shores, except in cases where they have been torn loose from their fastenings and carried by currents into the open sea. The Sargasso Sea of the Atlantic Ocean is merely an area outside of the track of the great oceanic currents and therefore constituting a huge eddy in which such material accumulates, growing vegetatively to a certain extent and finally dying and sinking.

If the only marine plants were in the benthos, in spite of the local luxuriance of its growth, the great mass of the ocean would be a desert, incapable of supporting anything like the amount of life which actually exists in it. There is, however, another great group of living organisms, the plankton. The plankton comprises those plants and animals that are neither attached to the bottom nor able to swim against a current, but normally live floating in the water and carried by it from place to place. Some of the animals of the plankton are of rather large size—such, for example, as the Portuguese man o'war and some of the larger jellyfish. Most of them, and all the plants, are microscopic. The plants, in fact, are all unicellular, although the cells are often united into filaments or colonies of various shapes. Two groups of plankton organisms are of special importance: the diatoms and the peridines.

The diatoms are unicellular plants occurring in all waters, but especially abundant in the colder parts of the ocean, growing in enormous numbers in the Arctic and Antarctic regions and reaching in temperate waters their maximum development in the cooler months of the year. They are unicellular organisms, enclosed in two silicious shells, one fitting over the other much as the lid fits the bottom of a pill box. In shape they are extremely varied, and the shells are usually marked with intricate patterns and often decorated with spines and knobs.

The peridines constitute a curious group of unicellular organisms intermediate between plants and animals. Some of them are holophytic or plantlike in their method of nutrition, others are saprophytic, absorbing dead organic material dissolved in the water, some are parasitic in the body cavity of small animals, such as copepods; a large number are holozoic, capturing and ingesting their food just as animals do. The peridines very largely replace the diatoms in the tropical seas, and in temperate waters attain their maximum numbers in the warmer months when the diatoms are at a minimum. This seasonal distribution is very possibly correlated with the diminution of the carbon dioxide content of the warmer waters. The peridines may be naked, or provided with a simple or elaborate armor of cellulose, the same material as that of which plant cell walls are composed. Whether armored or not, they are always provided with two flagella, one, hair-like, which trails behind them, the other a ribbon-like undulating structure typically encircling the body in a special groove provided for it and giving to the organism a rotatory motion.

In spite of their minute size it may fairly be said that the diatoms and the holophytic peridines are to the ocean what the grasses are to the land. What they lack in size is more than compensated for by their extreme abundance and rapidity of reproduction. Under favorable conditions hundreds of thousands of them may exist in a liter, so that the water is distinctly colored and is almost soupy to the touch.

A third group of important plankton organisms, entirely holophytic in their nutrition, is known as the *Coccolithophoridae*. These are brown-pigmented forms secreting very regular calcareous shells and occurring in the warmer parts of the open ocean. Most of them are extremely minute and while they are known to occur in extremely great abundance at times, because of their small size little is definitely known about their distribution or relative importance.

In addition to these groups of organisms, the zoospores and gametes of algæ are liberated in enormous number at certain seasons of the year, and add their contribution to the food supply of

the plankton, while there are numerous brown and green flagellates belonging to other than the three groups mentioned.

The phytoplankton exists everywhere at the surface of the ocean and for a considerable depth below the surface. Certainly it is fairly abundant as far down as a hundred fathoms in those parts of the ocean where the light approaches the vertical. It is, however, much more abundant near land than in mid-ocean, mainly because the organisms near land are in more immediate contact with the nutrient materials washed from the land into the sea, and tend to exhaust the supply before these materials reach the open ocean. The ratio between the number of plankton organisms near land as compared with the number in the open seas has been given as fifty to one, but this estimate, for reasons which will be apparent later, is probably much too high.

It is not enough to know life in the ocean qualitatively. It was long ago realized that it must be analyzed quantitatively. The earliest quantitative studies were those of Hensen, beginning about 1880, and modern work on the problem may be said to begin with him. He devised the forerunner of the present-day plankton net and attempted to account for the production of the sea by his collections. His nets missed all the smaller organisms and failed to secure many of the larger ones. Hensen realized this and attempted to allow for it in his calculations but his results were necessarily very imperfect. He succeeded in imparting new impetus to such studies, however, and deserves the credit due to a pioneer worker in a difficult field. The amount of food required by the animals of the sea is so much in excess of the amount shown to be produced by these early methods that Pütter (1907-1909) argued that the nutrition of marine animals was on an entirely different plane from that of land animals, and that a large number of them, especially the smaller ones, absorbed dissolved organic matter directly from the water without the mediation of plants. Pütter's arguments have not been generally accepted and more recent studies have invalidated many of them. Nevertheless, it is possible that something of this sort is more general than we realize. Mitchell has recently (1917) reported on experiments strongly indicating, although perhaps not proving, that so highly organized an animal as an oyster can utilize dextrose dissolved in sea water, transforming it into glycogen and storing it.

In 1911 Lohmann showed that many of the organisms that pass through the plankton net may be secured and studied by the use of a centrifuge. This, again, marked a great advance. He showed that these smaller organisms, for which he proposed the convenient term "nannoplankton," existed in enormous numbers in parts of the sea which the net collections seemed to show were barren,

and found that certain animals—*Appendicularia* e. g.—were very efficient collectors of these minute forms, sometimes feeding on them almost exclusively. Gran reports a similar experience in the Straits of Gibraltar. Net collections showed very little plankton in the water, but the stomachs of *Salpae* when examined were found to be crammed with forms too small to be retained by the nets. Even centrifuging fails to get many of these forms since they are often lighter than water or as light, or are so delicate that the operation destroys them. Allen has devised a dilution culture method similar in principle to those used in making bacterial counts. He adds to a quantity of filtered sea water a few drops of a nutrient solution, sterilizes it, and adds to it a known quantity of the sea water to be investigated—say, one cubic centimeter. After thorough shaking, this is poured into about a hundred sterile flasks and put in a north light for a few days. The flasks are then examined and the organisms that have developed in them identified, and the number of different kinds that are found in each flask are recorded. A given species is recorded only once from each flask and since at least one individual of the species must have been introduced to permit such development, the count is still too small. By actual experience this gave results of 464 organisms per cubic centimeter or 464,000 to a liter. Bacteria were disregarded. The centrifugal method applied to the same water gave a count of 14,450 to a liter. Allowing for duplication in some of the flasks and for the failure of many forms to develop under laboratory conditions Allen concludes that a count of 1,000,000 organisms per liter would be conservative. That is, one organism to each cubic millimeter. Assuming an average size equivalent to a sphere with a diameter of five microns, that is not excessively crowded, as the diagram will show. (Fig. 2.)

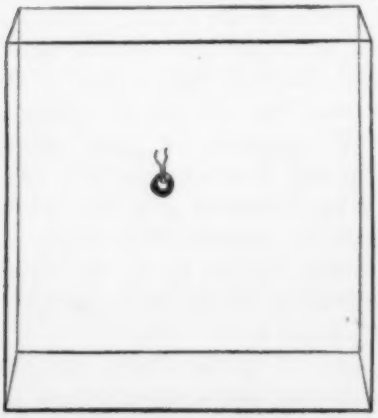


FIG. 2. COMPARATIVE SPACE OCCUPIED BY AN ORGANISM 6 MICRONS IN DIAMETER IN A CUBIC MILLIMETER (1/1,000,000 LITER) OF WATER

In this country, Moore, followed by Grave, attempted to calculate the "food value" or areas of water on the basis of similar plankton counts, working with special reference to the nutrition of oysters. They found out what organisms occurred in greatest numbers in the oysters' stomachs, studied the rate of feeding and then proceeded to collect and analyze samples of water over actual or potential

oyster beds, finding out just how many of these organisms occurred to the liter. They then carefully calculated the volume of each organism and by multiplying the volume by the number of times a given organism occurred in a unit volume of water and adding the totals, the "food value" was secured. This method gave much valuable information, but the results can not be regarded as final for several reasons. For one thing, organisms differing so widely as diatoms and peridines are not comparable on the basis of their volumes, as has been pointed out by Brandt and Juday. Again, in a locality where oysters are not naturally growing, their introduction often materially increases the supply of food, since their shells form substrata and their excreta help in the nourishment of numerous food organisms. Finally, they took no account of the food value of the nannoplankton nor of the detritus, which may be very considerable.

The most elaborate attempts to calculate the production of the sea have been those of the Danish biologist Petersen and his associates. As a result of their studies, these workers have come to the conclusion that the plankton plays a very small part in the nutrition of the animals of the sea and that the fundamental food of all marine forms in northern waters at any rate is the "dust-fine detritus" of the sea bottom, derived primarily from the eel-grass, *Zostera*. As an indication of the degree of progress which

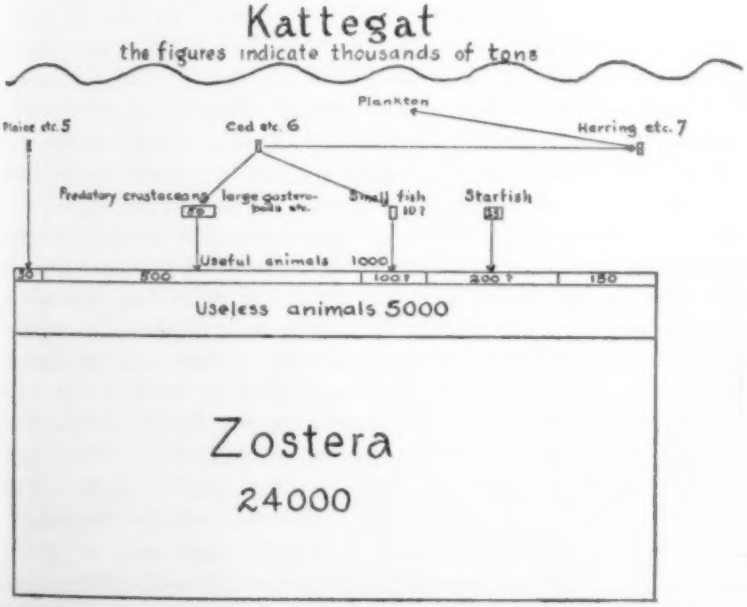


FIG. 3. ANIMAL LIFE IN THE KATTEGAT DERIVED FROM ZOSTERA, AFTER PETERSEN

these workers have made, the preliminary conclusions in the life in the Kattegat may be cited. The Kattegat is the rather shallow body of water between eastern Denmark and Sweden, having an extreme length of 150 miles and an extreme breadth of about 90 miles. It is assumed that about half of the total amount of *Zostera* annually produced in this area is washed elsewhere by the currents. The balance, estimated at 24,000,000 tons, serves as the basis for the animal life of the area. (See chart, Fig. 3.) The useless animals, that is, those that are of no value to man and do not serve as food for fish, feeding directly on the Zostera, amount to about 5,000,000 tons. Useful animals, mainly those capable of serving as food for fish, are estimated at 1,000,000 tons. These are not all utilized by food fish, however. Starfish account for perhaps 200,000 tons; 500,000 tons are eaten by the larger gasteropods and crustaceans, of which only a part are consumed by fish; while plaice and other flatfish consume about 50,000 tons, producing 5,000 tons of human food annually. Cod are much less economical, since they get their food at third hand, so to say, and each ton of the 6,000 tons produced annually represents about one hundred times as much of the original synthesized organic food. On the other hand, the cod help to keep down the predatory gasteropods and crustaceans. The herring is the most important food fish feeding on the plankton, (mainly on copepods) and it in turn is eaten by the cod. Perhaps the most striking feature brought out by these figures is the comparatively trifling amount of human food finally produced from such a large amount of organic material.

So much, then, for the life naturally existing in the ocean. How may our utilization of it be more intelligently directed? Obviously the most economical use of it as food would be for man or his domestic animals to eat it directly. So far as the use of algæ as food for human beings is concerned, we cannot expect, for the present at least, any considerable increase over the insignificant amount now consumed in the United States. In some countries algæ have been used as food for stock for centuries, and recent experiments have indicated that cheap and effective treatments may make possible a substantial increase in such use. It has recently been shown that the kelps exhibit wide variation in their carbohydrate as well as in their iodine content during the growing season and future utilization, to be profitable, must take such fluctuations into account so that the plants may be harvested at the proper season. We would not think of doing anything else in the case of a land plant. And it may be mentioned in passing that the old method of burning kelps for potash and iodine content

cannot be regarded as anything but a wasteful process even when temporary conditions permit it to compete with other sources of these products, as during the world war. Recent experiments in Sweden have suggested that dry distillation will yield, not only the potash and iodine formerly sought, but numerous other products, including illuminating gas, acetic acid, methyl alcohol, formic acid, acetone and creosote.

Since, however, man prefers to harvest the plant life of the sea indirectly, those animals which feed directly on the plants are able to increase with less waste and at a more rapid rate, considered in total populations, than those which feed on other animals. Most of our food fish, for example, feed on smaller fish; these in turn feed upon small crustaceans and the latter eat the microscopic plants and detritus, so that in many instances the fish we eat are removed three or four steps, perhaps more, from the original food source. This is more significant than may seem apparent at first glance, since it involves an enormous waste. Before any organism can grow, the energy needed merely to live must be supplied, and by the time a crustacean is eaten by a minnow, or a minnow by a food fish, it will, on the average, have consumed a quantity of food several times its own weight. These facts are well brought out in the diagram and statistics of Petersen, previously quoted. The edible shellfish, however—oysters, clams, mussels and the like—feed for the most part directly on the marine plants and this is one reason why the extension of the shell fisheries represents so much promise.

The carp is one of the few edible fish which lives directly on vegetable food. In the United States most people do not, it is true, regard this species as particularly edible but since it is largely eaten in Europe and raised for the purpose, it will serve as an excellent example of what such a fish may produce. The statistics on this fresh water fish are particularly valuable because they are not subject to the sources of error which hamper attempts to measure the productivity of the sea. The amount of fish produced in carp ponds has been calculated as ninety-five pounds on the average each year per acre. Brandt calculated the productivity of Kiel Harbor as eighty-nine pounds per acre annually, but the latter figures are much less exact. The average yield of beef on good land in the United Kingdom is seventy-three pounds per acre annually. The beef is much superior in food value, pound for pound, but it is also much more costly to produce. There are many inlets of the sea where conditions are almost as readily controllable as they are in the fresh water ponds. Such, for example, are the shallow enclosed sounds on the Atlantic coast of the United States

—Great South Bay in Long Island, Barnegat Bay in New Jersey, Albemarle and Pamlico Sounds in North Carolina and parts of Chesapeake Bay. These enclosed areas are at present producing a great deal of human food, but only a small part of what they might produce under proper management. On a larger scale, the Baltic and North Seas of Europe are similar regions where, if not sea culture, at least an intelligent harvesting of the seas' resources is yearly becoming more possible because of the careful studies which have been made by the English, German and Scandinavian biologists, whose countries are chiefly interested in the matter.

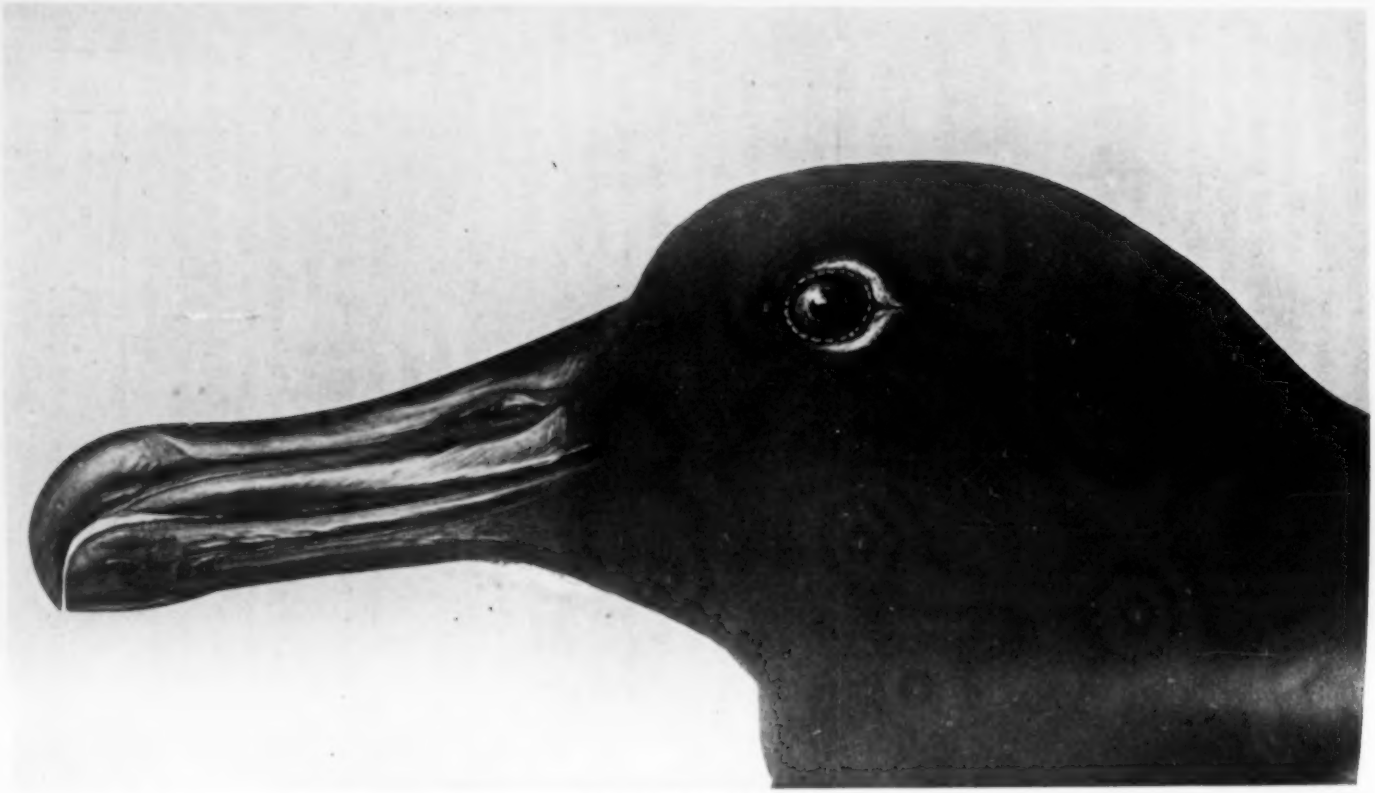
Before we can expect to make substantial advance we must have a much more comprehensive knowledge of the ecology of the sea than we have at present. For example, we may class the animals of the sea roughly into those which are valuable to man and those which are not, but when it comes to determining to which of these classes any particular species belongs, difficulties arise. The difference which direct and indirect utilization of food makes has already been pointed out. Some useful species which get their food at second or third hand, that is, by eating other animals, prey largely on forms that would not otherwise be converted into human food; some, on the other hand, eat species that are good human food. Thus, drumfish are good human food, but they may at times consume large numbers of oysters which are still more valuable to man than they are. Starfish, which are utterly useless forms, also attack oysters, but this case offers no perplexities. A very large number of animals are useless in the sense that they occupy space and consume food which might otherwise be utilized by useful species. The snails, sponges, sea anemones and some of the mussels of our northern waters belong to this group. However, in the case of most marine animals only a complete account of their life histories, together with the life histories of their associated forms is sufficient to enable us to know whether they are, in the long run, valuable or harmful from the human standpoint and whether it would be wise for us to attempt to overturn the balance which we find them maintaining in nature.

Another phase demanding careful study is the effect on the marine life of the waste materials which are constantly being poured into our waters, especially in the vicinity of our great cities. So far as industrial wastes and oil are concerned, the effect is wholly bad, and the questions at issue are: How much of this discharge is necessary? How can the pollution best be restricted to the necessary minimum? The sewage problem is more complex. The addition of large amounts of rich nitrogenous fertilizing material to our waters could be made a great source of wealth if it were

properly utilized, and even under our present hit or miss methods it results in a marked enrichening of the marine flora in favored localities. On the other hand, the danger of disease transmission is so well recognized and is illustrated by so many striking examples that large areas of sewage-polluted waters are eliminated as sources of food in whole or in part. How to utilize this valuable asset without endangering public health or spoiling the recreational value as well as the food value of our coastal waters is one of the biological problems of our day.

Finally, it may be reiterated that shellfish culture offers the most immediate hope for effective utilization of the sea's resources. The economy of direct utilization of plant food by these animals has been emphasized. Most shellfish, like land crops, stay where they are planted. Even the scallop, which can swim about after a fashion, is restricted in its movements and could readily be controlled. Oyster culture is already a great and important industry but it has not nearly approached its possibilities. Clam culture is still in an embryonic stage and scallop culture has as yet merely been suggested. When some of the problems confronting the establishment of these industries have been solved we may hope to have acquired additional information concerning the ecology of the sea which will help us in our approach to the more difficult problems of the future.

It is recognized that there are numerous economic phases involved in attempts to increase the productivity of the sea, but consideration of these would be beyond the scope of this paper. When social and economic forces demand additional food at reasonable prices, the biologists must be prepared to show where and how this may best be obtained.



HEAD OF THE SOOTY ALBATROSS

OUR GREAT ROVERS OF THE HIGH SEAS—THE ALBATROSS

By Dr. R. W. SHUFELDT

FELLOW OF THE AMERICAN ORNITHOLOGISTS' UNION,
WASHINGTON, D. C.

IN going over the literature devoted to ornithology, we find that but a small part of it refers to the birds known as Albatrosses. Alexander Wilson, the famous American ornithologist, never once mentions any of them in his work; and Audubon, who had splendid opportunities to study them in nature as well as in museums and private collections, touched upon those he had heard of, or studied skins of, in the lightest possible manner. In volume VIII of his work in my library, I note that he devotes but a single paragraph to the description of the genus (Diomedea). Apart from the description of characters, he gives but three and a half lines to the Yellow-nosed Albatross; a few lines more to the Black-footed Albatross, and four lines and a half to the Dusky Albatross—the last-named being the only one he figures. He was indebted to a "Mr. Townsend" for skins of all these species, the latter having collected them "not far from the mouth of the Columbia River."

As to the Black-footed Albatross, Audubon says: "It is clearly distinct from the other two described in his work, namely, the Dusky and the Yellow-nosed; but I have received no information respecting its habits. Not finding any of the meagre notices or descriptions to which I can refer to agree with this bird, I have taken the liberty of giving it a name, being well assured that, should it prove to have been described, some person will kindly correct the mistake." He named it *Diomedea nigripes*, the Black-footed Albatross, and it is the name we have for the species to-day.

In the last A. O. U. "Check-List" (1910), in addition to the bird just mentioned, we recognize four other species as belonging to the North American avifauna, namely, the Short-tailed Albatross (*D. albatrus*); the Laysan Albatross of Rothschild (*D. immutabilis*), and the Yellow-nosed and the Sooty Albatrosses (*T. culminatus* and *P. palpetrata*). These are all Pacific Ocean birds, though the Yellow-nosed species is said to have "accidentally occurred in the Gulf of St. Lawrence."

Personally, I do not recall ever having seen an Albatross in

nature; only a few of our ornithologists have, and, as just stated, neither Wilson nor Audubon fared any better. However, I have carefully examined quite a number of them in the collections of the United States National Museum; and not long ago, Dr. Charles W. Richmond, Assistant Curator of the Division of Birds of that institution, kindly loaned me the head of a specimen of the Sooty Albatross. It had no artificial eyes, and apparently was simply a head and nothing more—not even bearing any label or history. This head I photographed on side view, reducing it about one fourth, furnishing the print with an eye. That print is here reproduced as an illustration to my article.

Audubon's description of the beak of this species is so obscure as to be of but little value.

The plumage of the head—a rich snuff-brown—is soft and composed of fine feathers, and there is a narrow white stripe of short feathers surrounding the posterior half of the eye-lid on either side of the head. The beak is glossy black and formed as shown in the cut.

There is in existence a wonderful literature on the Albatrosses, especially when we consider how few species there are comparatively speaking. The old figures of them in the works are often very crude; while, upon the other hand, some fine photographic reproductions in different works are wonderfully fine and of great value. Among these are the remarkable photographs obtained by the Hon. Sir Walter Rothschild of the immense numbers of the Laysan Albatrosses, nesting on the island of that name; of the dreadful practice of carting away the eggs of that species, taken at the same place, and many others. Then Mr. Dudley Le Souëf, Director of the Melbourne Zoological Garden, has furnished us with a fine photograph of the White-capped Albatross on its egg, which latter, according to Professor Moseley, is held in a sort of pouch to be found between the legs of the bird.

Some species of these birds have a "tip to tip" measurement of the wings of no less than eleven feet and a few inches. It is a well-known fact that in the southern seas, where sailors have fallen overboard, they have been attacked in the water by one or more of these giants of the feathered race, and a poem on an incident of this sort would quite offset the experience of the ancient mariner who shot the albatross, which furnished Coleridge with the material for his famous verses.

The marvelous flight of one of these birds has been graphically described by Mr. Froude, who tells us that "the albatross wheels in circles round and round, and forever round the ship—now far behind, now sweeping past in a long, rapid curve, like a perfect skater on an untouched field of ice. There is no effort;

watch as closely as you will, you rarely or never see a stroke of the mighty pinion. The flight is generally near the water, often close to it. You lose sight of the bird as he disappears in the hollow between the waves, and catch him again as he rises over the crest; but how he rises and whence comes the propelling force, is to the eye inexplicable: he alters merely the angle at which the wings are inclined; usually they are parallel to the water and horizontal; but when he turns to ascend or makes a change in his direction, the wings then point at an angle, one to the sky, the other to the water."

The bird of this group usually referred to in prose or poetry is the Wandering Albatross (*D. exulans*); and it is said that specimens of it have been collected having an alar extent of no less than twelve feet. It is a bird with extraordinary power of flight, and Professor Hutton has well described the remarkable power these birds possess in that direction. "Suddenly he sees something floating in the water," says this authority, "and prepares to alight; but how changed he now is from the noble bird but a moment before, all grace and symmetry! He raises his wings, his head goes back, and his back goes in; down drop two enormous webbed feet, straddled out to their fullest extent; and with a hoarse croak, between the cry of a raven and that of a sheep, he falls 'souse' into the water. Here he is at home again, breasting the waves like a cork. Presently he stretches out his neck, and with great exertion of his wings runs along the top of the water for seventy or eighty yards, until, at last, having got sufficient impetus, he tucks up his legs, and is once more fairly launched in the air."

Another distinguished British writer on this subject, Professor Moseley, in describing their mating habits informs us that "when an albatross makes love, he stands by the female on the nest, raises his wings, spreads his tail and elevates it, throws up his head with the bill in the air, or stretches it straight out forwards as far as he can, and then utters a curious cry. . . . Whilst uttering the cry, the bird sways his neck up and down. The female responds with a similar note, and they bring the tips of their bills lovingly together. This sort of thing goes on for half an hour or so at a time."

There is great danger of the entire genus of Albatrosses becoming entirely extinct in the comparatively near future, and for several very good reasons. In the first place, many are shot and killed by passengers and others from the decks of vessels of all descriptions sailing on the high seas. This practice claims its quota every year, and no use is ever made of the poor birds thus ruthlessly slain. Again, many are caught with hook and line, but

these are usually released after being hauled aboard and giving an exhibition of their walking powers on the deck of the vessel. Another practice leading to their extinction—outranking all the others—is seen in the wholesale collection of their eggs for the markets of the western coasts of the Americas. The eggs used to be gathered, and still may be, on their breeding grounds, more particularly on the Island of Laysan, by the cartload, none being left for the perpetuation of the species. At least this was not looked out for in the early days of this most reprehensible trade. Whether it is still going on I am unable to say; but should it be, steps ought to be taken to bring it to an end.

In our bird fauna, the nearest relatives of the Albatrosses are the Fulmars, the Petrels and Shearwater. All these species possess the peculiar anatomy of the external nostrils—being designated in the vernacular as the Tube-nosed Swimmers, while in technical science the name *Tubinares* stands for the group.

THE PROGRESS OF SCIENCE

CURRENT COMMENT

By Dr. Edwin E. Slosson
Science Service

RELATIVITY AND THE ECLIPSE

On September 21 the theory of relativity was put to the proof. After the results of the photographs then taken have been measured we may perhaps know whether Einstein is to be ranked with Copernicus and Newton, among those who have revolutionized man's conception of the universe, or whether he will be regarded merely as the author of an ingenious mathematical theory of limited applicability to reality.

For the last three years the theory of relativity has been the topic of lively discussion extending far beyond the scientific circle, for the public realized that some interesting issues were somehow involved in its incomprehensible mathematics. More than a thousand books and uncountable articles have been published on Einstein; all sorts, *pro* and *con*, physical and metaphysical, experimental and speculative, serious and frivolous. Prizes have been offered for explanations in ordinary language. Personal, political, religious and racial passions and prejudices have been aroused. Einstein was the first German scientist to be welcomed since the war, in England, France and the United States, but in his own country he has to go into hiding to escape assassination by the junkers.

It is a remarkable example of how the progress of science may continue in spite of political conflict that during the world war Einstein should have sat quietly in his study in Berlin thinking out his theory and that during the world war English astronomers should have been quietly studying his work and preparing to put it to the test at the earliest opportunity.

This opportunity came on May 29, 1919, when there was a total eclipse of the sun. For Einstein had predicted that when the stars about the darkened disk of the sun were photographed they would appear as though pushed out of their positions. This is one of the consequences of his theory of relativity, which is designed to supplant, or at least to supplement, Newton's theory of gravitation.

According to Einstein, a ray of light from a star passing close by a heavy body like the sun is drawn out of its straight course a little, somewhat as though it were a stream of material particles, but to a greater extent than Newton's law would allow for. To an astronomer looking up at the star along this crooked path and not making allowance for the bend, it would seem that the star had been moved away from the sun a minute distance (1.74 seconds of arc). Of course this effect is the same at all times, but it can only be observed when the sun's disk is completely shadowed from us by the moon's coming between.

So the British astronomer royal, Professor Eddington, sent out two eclipse expeditions in 1919 to points where the eclipse could be observed, one to the west coast of Africa and the other to the east course of Brazil. When he came to develop and measure up his photographs, he found that the stars about the darkened sun were displaced in the direction and close to the amount predicted by Einstein.

This was good evidence in Einstein's favor, but scientists are cautious creatures and not all of them

THE WESTERN AUSTRALIAN ECLIPSE PARTY

World Wide Photos

The members of the eclipse party, photographed prior to their departure from Perth, Western Australia, for Wallal. Standing, left to right: J. Clark Maxwell, H. L. Quick, J. Hargreaves, J. P. C. Hoskinds, Dr. R. J. Trumpler, J. J. Dwyer, C. Nassiter, V. J. Mathews, C. S. Yates, Dr. J. H. Moore, G. M. Nunn. Sitting: Miss Chant, Mrs. Adams, Dr. C. E. Adams, Mrs. Campbell, Dr. W. W. Campbell, Mrs. Chant, Dr. C. A. Chant, A. D. Ross and Dr. Young.

were ready to accept so startling a theory as this without further confirmation. The weather was very cloudy in Africa, and the only good photograph obtained at the South American station was one taken with a four-inch lens and showing seven stars around the sun.

But there has been no other total eclipse observable till this year and this is not so good a one. There were no bright stars near the sun, in fact only one visible to the naked eye among those close enough to the sun so that their displacement could be measured. But there were four or five faint stars that may have been caught on a sensitive plate with a good telescope.

Unfortunately too, the eclipse occurred in a highly inconvenient part of the earth. Its track was along the Indian Ocean and through the heart of Australia where there are no observatories and few people. The best point was on Christmas Island, lying west of Australia and south of Java. This island only measures eight by twelve miles and has a population of about 250, according to the latest census. But it was selected by the British, German and Dutch expeditions for it was in the middle of the track of the eclipse. The darkness there lasted five minutes and astronomers can do much in five minutes. It appears, however, from cable despatches that the weather conditions were bad. An expedition from the Lick Observatory, California, was stationed on the west coast of Australia, and the Observatory of Adelaide sent a party into the arid interior of Australia, which involved five weeks of travel by camel train but which was pretty certain to get cloudless weather. In Australia the weather was favorable.

If the astronomical expeditions now in the field bring home confirmation of the results of the eclipse of 1919, then we may have to get used to all sorts of queer ideas, besides crooked beams of light in empty space. We may have to give up the force of gravitation and the ether and the constancy of mass and the distinction between matter and energy. We may get to talking about the curvature of time, the weight of heat, kinks in space, atoms of energy, four dimensions, world-lines and a finite universe. We may be called upon to come to conceive of arrows that shrink and bullets that get heavier the faster they travel; of clocks that go slower the faster they travel and of a future that turns back and tangles itself up in the present.

TANGLING UP THE TIME LINE

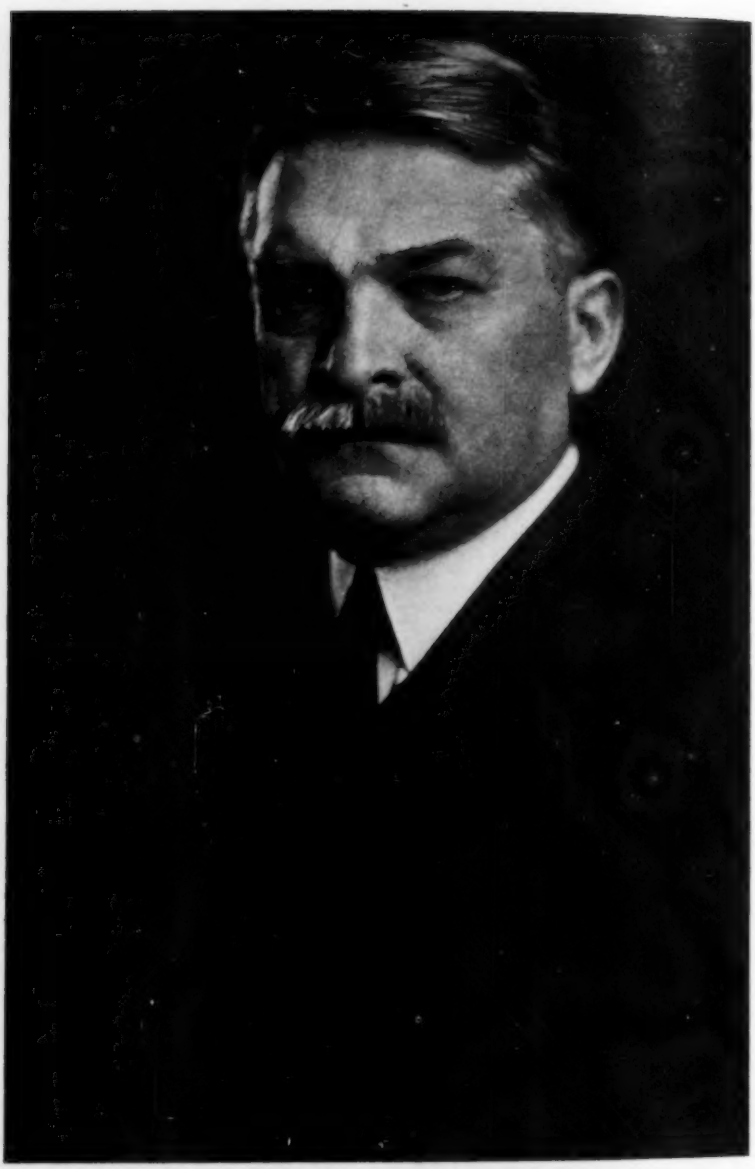
EINSTEIN'S theory of relativity is like a magician's bag. There seems to be no end to the queer things that can be pulled out of it. The more it is studied the more paradoxical it appears.

The latest thing I have seen is the queerest, the idea that the future may get tangled up in the present or even in the past. It is all worked out mathematically in a book just translated from the German, Weyl's "Time-Space-Matter." Too mathematical for most of us, but the point in plain language is this:

Here is a line representing the course of time extending from the dim past into the indefinite future:

Past | Future

The present is the point where I stand, looking both ways like Janus but not seeing any end in either direction. I am continually moving or being moved straight along the time road from left to right. Every instant I step from the past into the future. Every instant a bit of time is taken from the future and added to the past, though neither gets any smaller or larger since both are infinite. The past time and the future time are permanently separated by the moving present where I am and



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PRESIDENT SAMUEL W. STRATTON

Director of the Bureau of Standards since its establishment in 1901, now elected president of the Massachusetts Institute of Technology.

there seems no chance of the two kinds of time ever getting mixed up for they extend in opposite directions.

But wait—here's a disconcerting idea. If I roll up the paper I can make the future touch the past. I can overlap them. I can put A.D. into B.C. and what becomes of chronology then?

We are used to this curving of apparently straight lines in space ever since 1492 when men found that they were not living on a flat earth but on a sphere. If I travel straight east from this town I shall eventually come back to it from the west. How far I shall have to go depends upon where I live. If my home were on the equator, I should have to travel 25,000 miles to get to my starting point. If it were near one of the poles, I could do this astonishing stunt in the course of a morning's walk.

Now, according to Einstein, the time line is like the space lines. The framework of the world is measured by four dimensions, three of space and one of time, namely, the up-down, right-left, to-fro, past-future lines. But these are not rigidly fixed. They may be bent and distorted like a bird cage that has been twisted and crushed, though every wire remains intact and connected to the other wires just the same.

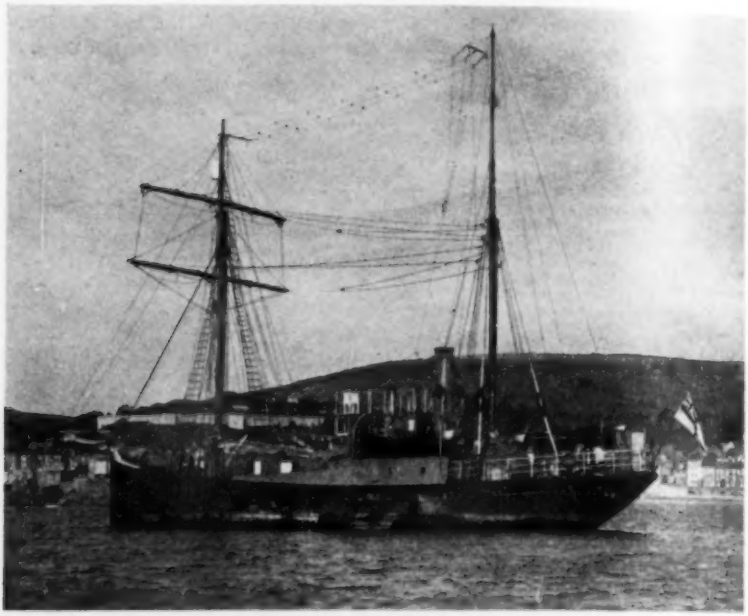
Wherever there is a bit of matter, wherever there are electrical or magnetic forces, there the time and space lines are more or less distorted. Einstein, reasoning from this idea, saw that a ray of light from a star, passing close by a heavy body like the sun, would not travel straight, but would be bent a little out of its course. The eclipse of 1919 brought the first chance to test Einstein's idea, and the astronomer royal of Great Britain went to Brazil and took a photograph of the shadowed sun and seven stars about it. And the seven stars seemed shoved out of their customary places just as if in the region around the sun the space and time were puckered up in the way Einstein said they were. When the eclipse of September 21, 1922, came, eight parties of astronomers were on the watch to see if the observations of three years before were confirmed.

We have not heard their verdict yet, but, if their photographs measure up according to Einstein formula we shall have to get accustomed to the idea that time—like the tariff—is a local issue; that time measurements like space measurements are relative, not absolute, and that we are not sure of the constancy of our standards of measure in either case. When two things happen in our presence we may be pretty sure which comes first. But if one event is here and another in Mars we can not be sure about priority with any conceivable system of clocks and signals. What seems past from one standpoint may seem future from another, for the time line may not run straight. Is your present condition in any way the result of your future actions? Can the light of a match be seen before the match is lit? Such a thing is conceivable in the generalized theory of relativity though, like most other conceivable things, it does not occur or is never known to occur in reality. But it is hard to get used to this strange new notion that the future may curl around in some sort of a circle and so come into the past.

Did I say "new"? It was a slip of the pen. For the idea is old. I open a volume of Egyptian antiquities and I see carved on a monument of the Pharaohs a serpent with its tail in its mouth, the symbol of eternity, of which time is a segment. But what the Egyptians merely guessed at Einstein is putting to the proof.

HOW THE CHEMIST MOVES THE WORLD

THE chemist provides the motive power of the world, the world of man, not the inanimated globe.



THE *QUEST* AT PLYMOUTH *World Wide Photos*

The *Quest*, the vessel of the Shackleton-Rowett Antaretic Expedition, on its arrival in Plymouth Harbor on September 16, after the expedition on which it embarked on September 17 of the previous year

Archimedes said he could move the world if he had a long enough lever. The chemist moves the world with molecules. The chemical reactions of the consumption of food and fuel furnish the energy for our muscles and machines. If the chemist can only get control of the electron, he will be in command of unlimited energy. For in this universe of ours power seems to be in inverse ratio to size and the minutest things are mightiest.

When we handle particles smaller than the atom, we can get behind the elements and may effect more marvelous transformations than ever. The smaller the building blocks, the greater the variety of buildings that can be constructed. The chemistry of the past was a kind of cooking. The chemistry of the future will be more like astronomy; but it will be a new and more useful sort of astronomy such as an astronomer might employ if he had the power to rearrange the solar system by annexing a new planet from some other system or expediting the condensation of a nebula a thousand times.

The chemist is not merely a manipulator of molecules; he is a manager of mankind. His discoveries and inventions, his economies and creations, often transform the conditions of ordinary life, alter the relations of national power and shift the currents of thought, but these revolutions are effected so quietly that the chemist does not get the credit for what he accomplishes, and indeed does not usually realize the extent of his sociological influence.

For instance, a great change that has come over the world in recent years, and has made conditions so unlike those existing in any previous period that historical precedents have no application to the present problems, is the rapid intercommunica-

tion of intelligence. Anything that anybody wants to say can be communicated to anybody who wants to hear it anywhere in all the wide world within a few minutes, or a few days, or at most a few months. In the agencies by which this is accomplished, rapid transit by ship, train or automobile, printing, photography, telegraph and telephone, wired or wireless, chemistry plays an essential part, although it is so unpretentious a part that it rarely receives recognition. For instance, the expansion of literature and the spread of enlightenment, which put an end to the Dark Ages, are ascribed to the invention of movable type by Gutenberg, or somebody else, at the end of the fourteenth century. But the credit belongs rather to the unknown chemist who invented the process of making paper. The ancient Romans stamped their bricks and lead pipes with type, but printing had to wait more than a thousand years for a supply of paper. Movable type is not the essential feature of printing, for most of the printing done now-a-days is not from movable type, but from solid lines or pages. We could if necessary do away with type and press altogether, and use some photographic method of composition and reproduction, but we could not do without paper. The invention of wood-pulp paper has done more for the expansion of literature than did the invention of rag paper 600 years ago.

Print is only an imperfect representation of the sound of speech, a particularly imperfect representation in the case of English because we can not tell how half the words sound from their spelling. But the phonograph gives us sounds directly, and the audion and the radio have extended the range of a speaker, until now a speaker may have an audi-

OFFICERS OF THE *QUEST* *World Wide Photos*

After the death of Sir Ernest Shackelton, Commander Frank Wild succeeded him as leader of the expedition. He is shown second from the left. In the center is Commander Wilson. Mr. Wilding is shown on the right with the camera.

ence covering a continent and including generations yet unborn. What these inventions do for sound, photography has done for the sister sense of light. By means of them man is able to transcend the limitations of time and space. He can make himself seen and heard all round the earth and to all future years.

SCIENTIFIC ITEMS

WE record with regret the death of Alexander Smith, formerly professor of chemistry at the University of Chicago and Columbia University; of Alice Robertson, formerly professor of zoology in Wellesley College; of David Sharp, formerly curator of the Museum of Zoology of the University of Cambridge and editor of the *Zoological Record;* of F. T. Trouton, emeritus professor of physics in the University of London, and of E. Bergmann, director of the Chemisch-Technische Reichsanstalt, Berlin.

SIR ERNEST RUTHERFORD, Cavendish professor of physics at the University of Cambridge, has been elected president of the British Association for the Advancement of Science in succession to Sir Charles S. Sherrington. The meeting next year will be at Liverpool; the following year the meeting will be in Toronto.

DR. ROBERT A. MILLIKAN, chairman of the board of the California Institute of Technology and director of the Norman Bridge laboratory of physics, has been appointed a member of the committee on intellectual cooperation of the League of Nations to succeed Dr. George E. Hale, director of the Mt. Wilson Observatory, who has resigned from the committee owing to the state of his health.

PROFESSOR W. L. BRAGG, of Manchester University, who, together with his father, Sir William Bragg, was awarded the Nobel Prize for physics in 1915, delivered on September 6 the lecture in Stockholm as prescribed by the statutes of the Nobel Institution.

THIS year's Silliman Memorial Lectures at Yale University will be delivered by Dr. August Krogh, professor of zoophysiology in Copenhagen University. Professor Krogh has taken for his general topic "The Anatomy and Physiology of Capillaries."